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NASA/ARMY XV-15 TILT ROTOR RESEARCH AIRCRAFT
WIND-TUNNEL TEST PROGRAM PLAN

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1. PROGRAM SCOPE

The joint NASA/Army XV-15 Tilt Rotor Research Aircraft Project involves design, fabrication, and flight test of two essentially identical aircraft. The overall plan to implement this program is documented in references 1 and 2. A Test and Evaluation Plan (ref. 3) outlines the tests to ensure that the XV-15 Tilt Rotor Research Aircraft will meet the requirements of the Program Plan and the Contract Model Specification and Statement of Work. As part of this plan, one of the aircraft will be tested in the Ames 40 × 80 Foot Wind Tunnel. These tests are to provide an initial assessment of the aerodynamic characteristics, structural loads, and rotor/pylon/wing dynamics in a simulated flight environment for correlation with estimated values. The results will be used for evaluation of the adequacy of preduction methods prior to flight tests. The tunnel speed capability includes all critical conversion and high blade load areas. The tests will also serve to verify the functional operation of the aircraft systems and on-board instrumentation in a flight environment.

Additionally, if problem areas are later encountered during the subsequent flight tests, or if it is desirable to investigate areas that can be more safely accomplished in the wind tunnel, the aircraft can again be put into the wind tunnel.

The purpose of this document is to define the management structure, operational plan, support requirements and responsibilities, safety provisions and reporting requirements for conduct of the wind tunnel tests and to relate the tests to other phases of the program.

2. APPLICABLE DOCUMENTS

The following documents, to the extent applicable, are made a part of this plan. Latest revisions of the reference documents will apply.

1. Ames Research Center, Guide for Planning Investigations in the Ames 40 × 80 Foot Wind Tunnel.

2. Planning Rotor Tests for the 40 × 80 Foot Wind Tunnel.

3. AHB 1750-1, Ames Research Center, Operations Safety, 40 × 80 Foot Wind Tunnel.

4. NHB 1700.1(VI), NASA Safety Manual, Volume 1, Basic Safety Requirements.

5. Appendix V, XV-15 System Safety and R&QA Plan, Contract NAS2-7800 Statement of Work.

6. AHB-6540-1, NASA-Ames Aircraft Maintenance and Inspection Manual.

7. XV-15 Maintenance and Inspection Manual.

8. BHT Report No. 301-099-003, Preliminary Interface Control Document for GFE/CFE Research Instrumentation.

9. BHT Report No. 301-959-001, XV-15 Aircraft Fuel Cells, Draining, Purging and Pressurizing Procedures.

10. XV-15 Flight Operators Manual.

11. BHT Report No. 301-993-001, Ground Tiedown Aircraft Test Plan for XV-15 (Model 301) Aircraft No. 1, Part 1.

12. Assembly Inspection Logs (AIL) (Aircraft Status Book).

13. Flight Test Workbook (Aircraft Service Workbook).

3. MANAGEMENT AND TEST DIRECTION

The Tilt Rotor Research Aircraft Projects Office will have primary management responsibility for the XV-15 Wind-Tunnel Test Program. This program will be supported by the Contractor and personnel of the 40 × 80 Foot Wind Tunnel, with assistance from elements of the Aircraft Operations Division and the Research Facilities and Instrumentation Division of Ames. Coordination of this effort will be the responsibility of the Project Office. The management structure for the Wind Tunnel Test Program is shown in figure 3-1. The principle elements of this structure are described in the following paragraphs.

3.1 Project Manager

The Project Manager is responsible for the overall operation of the Project Office and coordination with the Contractor and supporting elements within NASA and from other government agencies.

3.2 Deputy Manager (Technical)

This Deputy Manager is responsible for planning and coordinating the Wind-Tunnel Test Program, including organization of technical support and supporting research efforts. This includes the effort provided by the Project Office, the Contractor, the wind-tunnel staff, and other ARC supporting personnel.

3.3 Deputy Manager (Test and Operations)

This Deputy Manager has primary responsibility for project coordination, management control systems, aircraft configuration control, research instrumentation, Government Furnished Equipment (GFE), Aircraft Ground Equipment (AGE), Project Office effort related to reliability and quality assurance, and test safety.

3.4 Test Director

The Test Director is responsible for the Project Office support and coordination of the preparation for and conduct of the wind-tunnel tests. This includes:

- Preparation of a Test Plan and Schedule.
- Preparation of the Instrumentation List with priority requirements for data collection, reduction, analysis, and reporting.
- Completion or reviewing of the Systems Safety Analysis, test limits, and emergency procedures.
- Conduct of pre-test simulations for test crew and operator training in operating and emergency procedures.
- Support the Wind-Tunnel Test Readiness Review and Report with necessary documentation relating to elimination of hazards or minimizing risks disclosed by the Systems Safety Analysis.
- Monitoring preparation of the aircraft to ascertain that the provisions for testing will meet the requirements of the test objectives and that the aircraft is ready for test.
- With the test engineers, provide support for each shift during conduct of the test to monitor instrumentation displays to determine that the test is being conducted within established limits and ascertain any required modifications to the Test Plan and Schedule as dictated by test results or hardware/instrumentation problems.
- Assist in preparation and review of the report presenting the results of the wind-tunnel test.

3.5 Test Engineers

Test Engineers in support of the Test Director are responsible for the effort in their area of discipline including:

- Dynamics and stability and control
- Aerodynamics and performance
- Aircraft structure, structural dynamics, and aeroelastics
- Aircraft systems
- Instrumentation, data acquisition, reduction, and analysis

3.6 Project Control Officer

The Project Control Officer is responsible for arranging for procurement, transportation, shipping, and storage of project hardware and spares and maintains distribution control of the Wind-Tunnel Test Documentation.

4. OPERATIONS

The Wind-Tunnel Test Program includes preparation and checkout of the aircraft and systems, including special instrumentation, remote controls and other special hardware requirements for the conduct of the tests, data acquisition and analysis, reporting, and post-test refurbishment. Preparation for these tests will follow the requirements of references 4 and 5.

4.1 Schedule

The detail schedule for accomplishment of this effort is shown in figure 4-1. The relation to the overall program schedule is shown in figure 4-2. The various phases of the program leading to the Wind-Tunnel Test are described in the following paragraphs.

4.1.1 *Ground tiedown tests*- Following completion of the aircraft final assembly, the installed systems will be tested by the Contractor for interface compatibility and functional operation, including proof loading and calibration prior to ground testing of the complete aircraft. The tiedown tests will be conducted at the Contractor's facility. The purpose is to ensure proper functioning of all the aircraft systems during helicopter, conversion and airplane modes to ensure that the aircraft is safe for wind tunnel testing and exploratory flight testing. For the majority of the ground tiedown tests, operational control of the aircraft will be by a pilot in the cockpit.

For a portion of the tiedown tests of the wind-tunnel test aircraft, the remote control system and instrumentation for operation of the engines and flight controls during the wind-tunnel tests will be installed and functionally checked for proper operation. This checkout will duplicate wind-tunnel operation except that the ground tiedown tests will utilize the on-board fuel and hydraulic systems. Operation under remote control will be conducted to demonstrate hardware reliability and to train personnel that will operate the aircraft in the wind tunnel.

4.1.2 *Disassembly, Inspection and Shipment*- Upon completion of the ground tiedown development tests, the aircraft will be disassembled by the Contractor and a complete teardown and inspection will be made of the rotors, transmissions, drive system, and rotating control components. The inspected components will be refurbished or replaced as deemed necessary. Engine inspection will be conducted appropriate to the accumulated operating time or the severity of the operation. The aircraft will then be broken down into components and shipped to NASA/Ames by transportation suitable to the Government. An MTAR for disassembly, crating, packaging, tiedown, shipment, and reassembly will be provided by the Contractor. These tasks will be witnessed and approved by the Contractor's QA Inspector. Packaging and shipment will also be witnessed and approved by the Army Bell Plant Activity QA.

4.1.3 *Reassembly and Checkout*- After shipment and arrival at Ames, the aircraft will be reassembled by the Contractor. After assembly, a ground checkout will be conducted using the remote controls and control sonsole to functionally verify proper operation of all systems. Although the actual tests will be conducted in the Ames 40 × 80 Foot Wind Tunnel, other facilities at Ames will be utilized during the buildup, pre-test operational checkout and the post-test refurbishment. These include the static or tiedown test facilities is shown in figure 4-3. The majority of the assembly effort will be in the vehicle assembly building. This site is equipped with fuel, power and portable hydraulics so that preliminary checkout of the aircraft and systems for functional operation and calibration also can be conducted. The extent of this checkout and the facilities used will be determined by mutual agreement between the Tilt Rotor Project Office and the wind-tunnel staff. If it is more expeditious, part of this checkout may be conducted in the wind tunnel, such as final instrumentation checkout and calibration.

4.1.4 *Wind-tunnel tests*- Following completion of the reassembly and initial checkout, a Test Readiness Review will be conducted. This review will be initiated by the Large-Scale Aerodynamics Branch Test Operations Group Project Engineer and will be conducted in accordance with reference 4. The review serves to assure that all aspects of test operation safety have been properly considered. Ames, Contractor, and Project Office personnel will review, initial and date all items on the Test Readiness Review Form pertinent to the test. Ames management approval must be received before tests will be permitted to start.

4.1.4.1 Installation and pre-test checkout: The aircraft will be moved from the assembly building to the tunnel and installed. Control and instrumentation leads will be routed from the aircraft down the support struts to the control room. They then will be connected to the control console or the appropriate wind-tunnel instrumentation for data reduction, analysis, monitoring and recording. The instrumentation is described in more detail in section 4.2.6. Again the systems will be checked for continuity, functional operation and calibration. Following this, a shake test will be conducted.

4.1.4.2 Shake tests: A dynamic shake test of the combined aircraft, tunnel support system and balance system will be made after the aircraft is installed in the wind tunnel and prior to wind on testing to verify predicted mode shapes, frequencies and damping values of the aircraft as mounted in the wind tunnel. These tests will be conducted with the rotors off and with weights attached to the rotor hub spindles to simulate the rotor mass. The shake tests will be conducted by the wind-tunnel staff using the wind-tunnel shake test procedures and data analysis system as described in reference *6*.

Excitation will be applied to the rotor hub and/or selected airplane points with electro-hydraulic actuators. Accelerometers and/or strain gages will be used to measure the applied force and structural response. Structural damping will be determined using the wind-tunnel Dynamic Analysis System (DAS, ref. *4*). The data will be used for comparison with pre-test analysis and identification of frequency placements with respect to rotor rotational speeds to ensure that resonant vibration levels will not occur for operational rotor speeds. If resonance problems at operating conditions are identified, they will be corrected if feasible or the test plan will be modified.

4.1.4.3 Test operations: After the shake tests, the blades will be installed and runs made, wind-off, to check rotor track and balance. A functional check of the instrumentation in the rotating system will also be made.

Testing will follow the Test Plan (ref. 7). This includes rotors off runs to obtain baseline airframe characteristics. The tests with rotors on will consist of various phases of simulated tilt rotor flight at airspeeds from 0 to 200 knots. Blade angle, conversion angle (rotor tilt) and control setting will be varied to explore the performance, dynamics, stability, control, loads and noise characteristics in near hover, conversion and cruise configurations. The results of the wind-tunnel investigation will be compared to predicted values to be certain all critical mode analyses are valid and that the methods properly assess the dynamic characteristics, capabilities and operating behavior of the tilt rotor flight research aircraft. Wind-tunnel demonstrations of operational safety and of technical feasibility are required before initiating the subsequent task leading to flight research.

The Wind-Tunnel Test Operations Group (section 6.0 and ref. 8) has primary responsibility for management and safe conduct of the test in accordance with the Test Plan (ref. 7), and the safety procedures of references 8, 9, 10, and 11. Prior to each operating shift, a pre-shift meeting will be held between the *40* × 80 Shift Engineer and Project Engineer, Tilt Rotor Office Test Director and Contractor Project Engineer and rotor operators to detail the portion of the Test Plan to be implemented during that shift based on data results from completed portions of the test and to assure that the required aircraft systems, instrumentation and the wind tunnel and data acquisition system are operational. Limitations to test operation will be identified and any possible hazards with emergency procedures reviewed with the rotor and tunnel operators. During test operations, the assessment of the safety of a particular test condition due to structural loads or an instrumentation, electrical or mechanical failure and the authority to terminate or interrupt the test because of the hazardous condition, are the mutual responsibility of the 40 × 80 Shift Engineer and Project Engineer, Tilt Rotor Office Test Director and Contractor Project Engineer. Procedures and contingency plans to counteract emergencies will have previously been defined and approved (section 5 and ref. 4). If, in the judgment of any one of these individuals, a hazardous test condition exists, the test must be terminated until the condition is remedied or the test procedure modified.

4.1.5 *Post-test refurbishment*- Upon completion of the wind-tunnel testing, the aircraft will be removed from the wind tunnel and a detailed inspection made of the aircraft and dynamic components. The aircraft will be refurbished by the Contractor as required to bring the aircraft to flight status. The refurbishment will include removal of all instrumentation and hardware peculiar to the wind-tunnel testing, installation of all instrumentation, ballast and other hardware necessary for conduct of the flight test program. If any modifications to the aircraft are made as a result of a review of the wind-tunnel test results, qualification tests will be conducted as required for new, repackaged, or modified components and assemblies. A ground run will then be performed by the Contractor to complete the pre-flight and functional ground test requirements prior to releasing the aircraft for flight.

4.2 Aircraft Preparation and Remote Systems

A general description of the wind tunnel, the aircraft support system, and installation requirements are given in reference 4. In order that the XV-15 aircraft may be mounted and operated in the tunnel, certain provisions or modifications to the ship's structure and hydraulic, fuel, electrical, and control systems are required. These provisions and modifications are described in the following paragraphs.

4.2.1 *Support system*- The aircraft is supported in the wind tunnel on a system of three struts as described in reference 4. To accept the loads imposed by attachment to the support struts, additional structure has been added to the wing and fuselage in the attachment area. Consideration was given to dynamic requirements in selection of the location of the attach points. Mounted on these attach points are removable adaptor fittings (BHT dwg 301-099-017 and -018) to which are attached the support strut ball socket tip fittings (ARC dwg A5005-D200). The adaptor fittings are contractor designed and fabricated. The ball socket fittings are supplied by Ames. Structural integrity of the strut attach points and fittings was verified by proof load tests.

The installation of the aircraft in the wind tunnel is shown in figure 4-4. Various strut and tip arrangements are available (table I). Consideration was given to dynamic characteristics and clearances (fig. 4-5) in selecting the strut arrangement. Because of an interference between the landing gear doors (gear down) and the support struts, it is planned to conduct all tests with gear up and the gear doors on and closed.

Clearances for hoisting the aircraft in the tunnel are shown in figure 4-6. Although this figure indicates rotors on, it is planned to remove the rotors prior to lift in.

4.2.2 *Remote control system*- Tests of aircraft in the Ames 40 × 80 Foot Wind Tunnel which require operation of gas turbine engines utilize remote operation of engine and flight control systems because of safety considerations necessitated by the particular tunnel design (closed return and minimal air exchange). For the XV-15, remote operation of the controls will be through actuators installed in the aircraft systems as shown in figure 4-7. The controls for operation of these actuators, along with the instrumentation for monitoring the conditions of the various system for the remote operation, will be located and displayed on a control console, The layout of this console is shown in figure 4-8. The console will be located in and operated from the wind tunnel control room (ref. 4 and fig. 4-9). The remote control system will be designed and built by BHT and installed in the aircraft and checked for functional operation during the latter portion of the Ground Tiedown Test of the aircraft (ref. 12).

4.2.3 *Fuel system*- Normal 40 × 80 Foot Wind Tunnel procedures for safe operation of engines in the wind tunnel require external supply of fuel. Therefore, the ship's fuel tanks will be purged and inerted as described in appendix A. The fuel lines to the engines will be connected to the wind tunnel supply system and the ship's crossfeed valve opened (fig. 4-10). Fuel lines to the ship's tanks will be disconnected and capped to prevent fuel from entering the ship's tanks. A fuel shutoff valve operated from the console will be installed in the wind tunnel supply line where it enters the wing which will shut off fuel to both engines. In addition, a fuel shutoff valve is located in the aircraft at each pylon and is controlled from a switch in the fuel control panel that will be removed from the aircraft and installed in the console. This valve also closes when the fire extinguisher handle is pulled.

It will be the responsibility of the contractor to inert the fuel tanks and provide for connections to the ship's system. Ames will have the responsibility for providing fuel to the connection of the ship's system with a shutoff valve and filter (fig. 4-11). Prior to the test, the cleanliness of the wind tunnel supplied fuel will be ascertained to determine that it is satisfactory for connection to the ship's system.

4.2.4 *Hydraulic systems*- The ship's hydraulic system for operation of control actuators and motors consists of three independent systems which provide redundancy (ref. 13 and table 11). The systems are supplied from transmission driven hydraulic pumps. For the tests with engines operating, the ship's system will be operating. To provide capability for operation of the aerodynamic controls (flaps, flaperons, rudders, and elevators) with rotors and power off when the ship's system would not be operating, one of the ship's hydraulic systems (PC-2) will have provision for external connections to the wind tunnel hydraulic system through an interface system as shown in figure 4-11. The contractor will provide the fittings in the PC-2 system hydraulic line within the wing structure at the support strut location for connection to the interface system (fig. 4-12). The design of the interface will be provided by the contractor. Ames will provide the wind-tunnel hydraulic system and the interface with the ship's system. Ames will have the responsibility to determine the cleanliness of the tunnel system to determine that it is satisfactory for connection to the aircraft system. For pre-run (power off) checkout of the systems, calibration and troubleshooting, access to the PC-1 and PC-3 ship's systems will utilize connections in the left main gear wheel well through a temporary external line to the wind-tunnel interface system.

4.2.5 *Electrical system*- When the aircraft is mounted in the wind tunnel, electrical power will be required for:

Pre-run checkout and troubleshooting
Starting
Operation of remote control actuators
Instrumentation
Operation of aircraft electrical systems for those test runs with rotors off and engines not running

Normal operation of these systems on the ground is through use of a ground cart connected to the external power plug in the fuselage. For the wind-tunnel operation, electrical power is supplied from fixed DC generator sets (ref. 4) through wiring up the support struts to the aircraft systems (fig. 4-13). The design and provisions for connection of the aircraft systems to the wind-tunnel power supply will be the responsibility of the contractor. The wiring for the tunnel installation is shown in BHT dwg 301-099-014.

4.2.6 *Research instrumentation and data acquisition*- Research instrumentation for the wind-tunnel test consists of the aircraft on-board systems (ref. 14) and the wind tunnel data acquisition system (ref. 4). The on-board systems consist of sensors, data acquisition, signal conditioning, encoding and recording (PCM tape). The contractor has the responsibility to select and program the on-board data acquisition system to satisfy the data requirements of the wind tunnel test plan. The contractor shall also conduct pre- and post-run calibration and functional checks of the on-board system to ensure its accuracy and functional capability and assist the tunnel staff with the aircraft/tunnel interface.

The wind-tunnel data acquisition system is described in reference 4 and has conditioning, monitoring, reduction, analysis, display, and recording capabilities. The responsibility for implementation, operation, and maintenance of this instrumentation and its interface with the on-board system is a combined effort between the wind-tunnel staff and Ames support services.

The on-board research instrumentation and the interface with the 40 × 80 data systems are listed in tables III and IV and shown in figure 4-14. When the detailed run by run test plan has been established, this instrumentation list will be prioritized to indicate critical channels which must be operative for either safety or data requirements.

During the wind-tunnel test, the on-board PCM tape recorder will be installed in the control room to provide access during a test run.

4.2.7 *Computation and data reduction-* Requirements for computation and data reduction and display will be established and detailed in the Wind-Tunnel Test Plan (ref. 7). Included will be the type and format of data for monitoring and recording and the calibration and corrections to be applied and summary and reformatting requirements. Portions of this computation and data reduction will be done on-line and displayed and recorded. The rotor/wing/pylon dynamic stability and system damping will be analyzed on-line using the wind-tunnel Dynamics Analysis System (ref. 4) and the on-board dynamic excitation system. To facilitate this analysis, direct access will be provided to certain sensors on the wing and pylon (table IV). Following the test, additional computation and data reduction may be required and will be provided by the Computation Division through computer terminals at the wind tunnel. Implementation of the computation and data reduction is the responsibility of the wind-tunnel staff.

4.2.8 *Configuration control-* The aircraft will be under configuration control as defined in the Program Plan. All Engineering Change Orders involving aircraft modification or component installation will require NASA/Army coordination. A configuration sheet in the aircraft log book will maintain status of permanent or temporary deviations from the as-built configuration. Test items installed temporarily will require an entry in the aircraft log book. Assembly Inspection Logs (AIL) for serialized assemblies will be maintained.

5. PROGRAM SAFETY

The principal system safety objective for the XV-15 Tilt Rotor Research Aircraft Project is the completion of all project objectives without personnel injury or loss of life and without significant property damage or loss. Assuring accomplishment of this objective involves preparation of safety plans, identification of responsibility of all involved participants, adherence to applicable criteria and the provisions for safety analysis reviews and analysis of the test system. The test system is defined to encompass the aircraft and its components, interfacing subsystems, equipment, instrumentation and test crews. Requirements, provisions, and responsibility for assuring safe conduct c. the wind tunnel tests at Ames are defined in references 8 to 11. These references enumerate the specific analysis and documentation to be submitted to the Ames Management prior to start of testing and include problem,' failure reporting, wind tunnel operating hazard analysis and incident and/or accident investigation and reporting procedures and responsibilities.

5.1 Systems Safety Analysis

The Systems Safety Analysis Report is the primary document which enumerates the aircraft and test operation safety provisions for conduct of the wind-tunnel tests. This document will be prepared by the contractor in accordance with reference 4 and submitted for approval at least 30 days prior to start of testing. The Safety Analysis will consist of a gross hazard study or comprehensive assessment of the safety features of the aircraft and test systems to adequately evaluate the wind-tunnel test procedures, precautions, facilities, and capabilities in relation to applicable safety criteria to verify that the XV-15 may be safely tested in the wind tunnel. The safety engineering analysis shall be made in sufficient depth to assure maximum safety consistent with operation requirements. Special emphasis will be placed on emergency procedures and other safety features. Additionally, the safety analysis will include pre-test predictions of loads, fatigue life, and dynamic stability to establish boundary conditions for safe test operation.

5.1.1 *Pre-test analysis-* A pre-test analysis will be made by the contractor which will include an estimate of loads on critical members, flapping angles, dynamic modes, and level of stability to cover expected conditions within the test envelope. A written summary will be furnished at least 2 months prior to the tests.

5.1.1.1 Loads and strength evaluation: For the airplane as mounted on the support system in the wind tunnel, the contractor will provide estimates of the maximum loads, both steady and dynamic, to be expected during the wind tunnel tests and calculate the strength, safety margins and fatigue life of critical elements. The analysis will also include hoisting slings, strut adaptors, and any other structural components used for the wind tunnel test. Substantiation of these estimates will be made where test data is available. Components are considered critical if failure could result in loss of the aircraft, personnel injury, damage to the tunnel or scale system, or termination of the test. The maximum loads expected to be imposed on the struts and scale system will also be calculated by the contractor to assure that they are within the capacity of these systems as stated in reference 4.

5.1.1.2 Dynamic stability: The contractor will estimate the aircraft and rotor stability boundaries for comparison with the test operating boundaries. The coupled aircraft, tunnel support and balance dynamics will also be analyzed to determine potential resonances. The 40 × 80 foot wind tunnel staff will make an independent analysis. If resonance problems at operating conditions are indicated, recommendations will be made for change in stiffness and/or mass characteristics to avoid potential resonances or the test plar will be modified to avoid the resonances. After the aircraft is installed in the wind tunnel, shake tests will be made prior to wind on testing to verify predicted mode shapes, frequencies, and damping values.

5.1.2 *Simulation and crew training-* Prior to the wind-tunnel tests, crew training in operation of the remote systems will be conducted. This training will occur during the latter part of the Ground Tiedown Test at the contractor's facility following installation and functional checkout of the remote system (section 4.1.1).

Also, if time and facilities availability permit, it is planned to conduct a simulation of the test operation at Ames using components of the FSAA simulator. This simulation will:

- Evaluate procedures for safe operations of the aircraft in the wind tunnel.
- Train operators in both normal and emergency operating procedures.
- Provide a pre-test wind-tunnel data predictions capability to evaluate operating conditions for proximity to boundaries and identify potentially dangerous emergency conditions.

This simulation will use the complete aircraft math model without FFS or SCAS that was used for the flight simulation. Inputs to the math model will be adjusted to correspond to the aircraft as mounted in the wind tunnel.

The simulation will be conducted in-house. If feasible, the simulation will include an operator training portion and will involve both the 40 × 80 foot wind tunnel and contractor personnel.

5.1.3 *Operation and monitoring procedures*- As part of the Systems Safety Analysis, the contractor will define test start up and shutdown procedures, identify all probable failures in the various aircraft and tunnel systems and evaluate their impact on the safe operation of the test. He will determine their probability of occurrence and resulting hazards and develop emergency procedures to cope with the failure.

Procedures for monitoring specific test parameters for determining proximity to test boundaries, load limits, etc. will be provided by the contractor prior to the test in the form of an Instrumentation Test Plan. This plan will show in detail the components instrumented, instruments used, circuit diagrams, and calibrations. The instrumentation list will be prioritized to indicate which channels must be operative to start or to continue each test run. Additional details of the data acquisition system are given in section 4.2.6.

Any incidents or accidents that occur will be investigated and reported in accordance with the requirements of reference 11.

5.1.4 *Fire protection*- A fire detection and extinguishing system is incorporated in the aircraft. This system is pilot operated. For the wind-tunnel tests, the fire indication and operation of the extinguishing system will be moved from the cockpit to the remote control console (fig. 4-8). The fire extinguishing system also includes a fuel shutoff at the pylons which closes when the fire handle is pulled. Additional control of fuel flow is described under Fuel System in section 4.2.3.

5.1.5 *Emergency egress system*- An emergency egress system is installed in the aircraft for flight operations and includes pilot and co-pilot ejection seats (ref. 15) and emergency release side and overhead panels. For the wind-tunnel tests, the ballistics for the ejection seats and the detonator chord for window release will be either removed, disarmed or otherwise safetied. The contractor has responsibility for deactivation of the egress system.

5.2 Viewing System

Because of hazards from parts that may be released as a result of a structural failure on the aircraft most of the tunnel sides, including viewing windows, are covered with armor plate. Visual monitoring of the aircraft in the tunnel during the test will be provided by closed circuit television (ref. 4) using four remote TV cameras having scan and zoom capability. The system has provision for 10 camera locations and includes 3 video recorders and 5 monitors.

5.3 Test Readiness Review

To assure that all aspects of test planning, operation safety, and emergency procedures have been properly considered prior to start of tests all items pertinent to the proposed tests will be reviewed by personnel from the wind tunnel, project office, and the contractor. The Test Readiness Review and other checklists will be submitted to the 40 × 80 foot wind tunnel operations manager and branch chief for review and approval. Approval is required before tests will be permitted to start.

6. SUPPORT REQUIREMENTS

Although the overall direction, management, and coordination of the wind tunnel test program is the responsibility of the XV-15 Project Office, accomplishment of the detailed tasks is a combined effort by many groups. These include:

Contractor
Large Scale Aerodynamics Branch
Aircraft Services Branch
Aircraft Inspection Branch
Simulations Investigations Branch
Photo Technology Branch
Computer Systems Branch
R&QA Office

Primary support for the wind tunnel tests is provided by the Ames Large Scale Aerodynamics Branch through their Test Operations Group and Rotary Wing Group. Supporting services from other organizations at Ames is authorized by reference 16. The organizational structure for the supporting services is shown in figure 6-1 and 6-2. Much of the support effort is a dual responsibility with overlapping assignments for various phases of the support requirements. These include:

Planning
Hardware
Operation
Reporting

The distribution of responsibility is summarized in table V.

7. REPORTING AND DOCUMENTATION

Prior to, during, and following the tunnel test, various planning documents, schedules, progress and data reports will be required. Some of these have been discussed in other sections and are included in the following summary of the documentation and repcrting required for the wind-tunnel test. These include:

- Test Plan
- Instrumentation Plan
- System Safety Analysis
- Wind Tunnel Operating Hazard Analysis
- Failure Reporting
- Incident/Accident Reports
- Test Readiness Report
- Test Emergency Procedures
- Engine/Rotor Operators Run Checklist
- Test Report

In addition to the above, certain wind tunnel related documentation is required to assure proper operation of support equipment during the test. These are described in reference 8 and include:

- Preparation Checklist
  - Test Section
  - Instrumentation
  - Aircraft Mechanics
- Balance House Pre-Run Checklist
- Preventive Maintenance Work Sheet
  - Mechanical
  - Electrical

Preparation of these latter documents is the responsibility of the Tunnel Operations Group and are usually implemented on either a regular maintenance schedule or as part of the test preparation.

7.1 Test Plan

A plan for conduct of the wind tunnel test shall be prepared and submitted by the contractor in accordance with the requirements of references 4 and 5. A draft version of the plan shall be submitted twelve (12) months prior to the test which shall include a brief discussion of test objectives, scope and duration, and indicate test techniques, range of test variables, test configurations and data requirements. Details of the plan shall be finalized and submitted two (2) months prior to the test and include a detailed description of each run stating the test configuration, test variables, and instrumentation and data reduction.

The Test Plan shall also define the specific government/contractor personnel requirements and responsibilities, sharing of instrumentation, data reduction and operations tasks.

7.2 Instrumentation Plan

Data requirements for the wind-tunnel test are identified in the Test Plan. The instrumentation for this data measurement is described in reference 14. For the wind-tunnel test, an Instrumentation Plan shall be prepared and submitted by the contractor showing in detail the components instrumented, sensor calibrations and expected ranges, circuit diagrams, and the interface with the wind-tunnel instrumentation, and the instrumentation and display requirements. The instrumentation list will be prioritized to indicate which channels must be operative for either safety or data requirements. All critical channels must be operative prior to start of each run. Failure of any critical channel will require termination of the run.

From this plan, the Wind-Tunnel Instrumentation Group will prepare an instrumentation document detailing the interface and instrumentation and display requirements and the sensor channel location on each of the wind-tunnel instruments and displays.

7.3 Systems Safety Analysis Report

A report presenting the results of the systems safety analysis described in section 5.1 shall be prepared and submitted by the contractor. As indicated in reference 5, portions of the report are required to be submitted up to six (6) months prior to the test date. The complete report is required (1) month prior to test.

7.4 Wind-Tunnel Operating Hazard Analysis

A hazard analysis will be performed on hazards that could occur during the wind tunnel test. The analysis will consider those procedures unique to wind-tunnel operations. Reports of pertinent hazards will be presented in a format determined by the contractor.

7.5 Failure Reporting

Failure and Maintenance Action Reports shall be prepared and submitted by the contractor in accordance with NAS2-7800 reporting requirements. These reports shall be prepared and submitted in standard contractor format.

7.6 Incident/Accident Reports

Requirements for Incident/Accident investigations and reporting procedures and responsibilities are defined in reference 11.

7.7 Test Readiness Report

The Test Readiness Report is described in reference 8 and section 5.3. This report must be submitted for review and approved by the Wind-Tunnel Operations Manager and Branch Chief before tests will be permitted to start.

7.8 Test Emergency Procedures

Emergency operation procedures are developed as part of the Systems Safety Analysis. These procedures will be prepared and displayed in a format readily available to the operators and test engineers during test operation. Prior to each run, the applicable procedures will be reviewed and during any emergency these procedures will be strictly adhered to.

7.9 Engine/Rotor Operator's Checklist

In accordance with the planning requirements of reference 4, an operator's run checklist will be prepared. This list will be displayed where it will be readily available to the operators during test operations, and will include procedures for:

Pre-start
Start
Operating limits
Monitoring and data requirements
Shutdown

7.10 Test Report

A final wind tunnel test report shall be prepared by the contractor. This report shall include a statement of the test objectives, test procedures, test configuration, a discussion of the test results, and conclusions. The review of the results shall include recommendations as to whether modifications to the research aircraft are desirable prior to initiation of the flight program.

8. REFERENCES

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4. Guide for Planning Investigations in the Ames 40 × 80 Foot Wind Tunnel, June 1975.

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7. Marr, R. L., Test Plan for the XV-15 Tilt Rotor Aircraft in the ARC 40- by 80-Foot Wind Tunnel, BHT Report 301-083-005, October 3, 1977.

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9. XV-15 Systems Safety and R&QA Plan, Appendix V to Contract NAS2-7800, October 1973.

10. NASA Safety Manual, Volume 1, Basic Safety Requirements NHB 1700.1(VI).

11. Ames Research Center Safety Manual AHB 1700-1, January 1975.

12. Leibensberger, C. E., Ground Tiedown Aircraft Test Plan for XV-15 (Model 301) Aircraft No. 1, Part I, BHT Report 301-993-001, November 23, 1976.

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14. Instrumentation and Data Acquisition Manual, BHT Report 301-099-003B, June 28, 1974.

15. T.O. IL-1OA-2-3 LW-3B Aircrew Escape System.

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APPENDIX A

FUELING PROCEDURES FOR WIND TUNNEL OPERATION

A1.0 Wing Tank Defueling Procedure

The following defueling procedures are to be used for the BHT 301-060-600 fuel system installation (wing) in preparation for the wind-tunnel tests (reference BHT dwg 301-099-016).

A1.1 Aircraft to be as level as possible.

A1.2 Observe the requirements of BHT Report 301-959-001, XV-15 Aircraft Fuel Cells, Draining, Purging and Pressurizing Procedures.

A1.3 Attach a hose to the defuel valve. The open end of the hose must be passed overboard and placed in a reservoir so that gravity will permit fuel to be drained. Existing cap must be removed before hose can be attached.

A1.4 Open the defuel valve. This is operated manually by a handle on the valve.

A1.5 From the pilot's console, position the switch that operates the equalizer valve to the open position (read TANK INTCON).

A1.6 When the tanks are depleted of fuel, close the defuel valve and disconnect the drain hose.

A1.7 Operate the sump drain valves (one in each wing) catching the fuel in a container until the tanks are empty.

A1.8 Purge the tanks observing safety instructions of BHT Report 301-959-001.

A1.9 Break into the vent lines at the points indicated and add one cap in each wing to the tank side portion of the line.

A1.10 Attach a hose to the defuel valve (or more convenient opening to tanks). Attach the other end of the hose to the nitrogen supply. Add the system pressure relief valve and the system pressure gage to the nitrogen supply as shown on BHT dwg 301-099-016. With the defuel valve and the equalizer valve in the open position, fill the cells per safety instructions.

Note: If alternate opening is used, the defuel valve must be closed.

A1.11 Follow the safety plan to the conclusion of the purge procedure.

a

A2.0 Fueling Procedure Preparation

Following are the fueling procedures in preparation for the wind tunnel tests.

A2.1 Break the crossfeed line as shown on BHT dwg 301-099-016 and add (2) AN929-10 caps (1 L/H and 1 R/H) to the existing tee fittings.

A2.2 Plug and stow the hose with AN 806-10D plug, L/H and R/H.

A2.3 Operate the crossfeed valve to the open position by operating the switch on the pilot's console (reads FUEL XFEED).

A2.4 On the R/H wing only, open the existing line by removing a cap on the tee provided.

A2.5 Attach the hose indicated to the open port in the tee. Add the connectors as shown. Add the filter and the upper tube as indicated. Add the middle tube and the tee to the base of the filter as shown. The tee must have (2) unions and (2) packings assembled to the tee prior to the attachment of the tube assemblies. Attach the busing or reducer with (1) MS 29512-10 packing. Add the pressure switch and (1) MS 29512 packing. Wire as indicated. Add the lower tube assembly to the base of the tee. Add the valve after attaching (2) connectors as shown.

Note: The items in this step of the procedure to be installed on the inside or the outside of the wind-tunnel strut fairing as determined by NASA personnel.

A2.6 Attach the hose from the valve to the facility regulator.

Table I.- Angle of Attack Range for the XV-15 in the Ames 40- by 80-Foot Wind Tunnel

MAIN STRUT (FEET)	MAIN TIP (INCHES)	AFT TIP (INCHES)	AFT EXT.	α RANGE − ③	α RANGE +	ROTOR ℄ LOC. (INCHES) ②	STRUT TILT FWD	STRUT TILT AFT	
15	6	12	IN	$18\frac{1}{2}$	$11\frac{1}{2}$	−39	$-\frac{1}{2}$	$3\frac{1}{2}$	
15	6	24	IN	$21\frac{1}{2}$	9	−39	0	$3\frac{1}{2}$	
15	6	36	IN	$22\frac{1}{2}$ (1)	6	−39	1	$3\frac{1}{2}$	
15	6	48	IN	$22\frac{1}{2}$ (1)	3	−39	2	$3\frac{1}{2}$	
15	6	48	OUT	$7\frac{1}{2}$	$22\frac{1}{2}$ (1)	−39	$14\frac{1}{2}$	$3\frac{1}{2}$	
15	33	12	IN	$12\frac{1}{2}$	18	−12	$4\frac{1}{2}$	$2\frac{1}{2}$	④
15	33	24	IN	$15\frac{1}{2}$	15	−12	2	$2\frac{1}{2}$	
15	33	36	IN	$18\frac{1}{2}$	$12\frac{1}{2}$	−12	$\frac{1}{2}$	$2\frac{1}{2}$	
15	33	48	IN	21	$9\frac{1}{2}$	−12	$\frac{1}{2}$	$2\frac{1}{2}$	
15	60	12	IN	6	$22\frac{1}{2}$ (1)	+15	11	2	
15	60	24	IN	9	$22\frac{1}{2}$	+15	7	2	
15	60	36	IN	$11\frac{1}{2}$	19	+15	4	2	
15	60	48	IN	15	16	+15	2	2	

① BALL SOCKET LIMIT $\pm 22\frac{1}{2}°$
② + ABOVE TUNNEL ℄, − BELOW
③ ROTOR/FAIRING INTERFERENCE LIMITS NEGATIVE α
④ STRUT TIP ARRANGEMENT [illegible]

TABLE II .- WDRALJLIC POWER DISTRIBUTION

Component	Type	PC 1	PC 2	PC 3
		Subsystem		
		Swivel location		
		outboard (pylon)	inboard (pylon)	inboard (spindle)
		Pump location		
		L/H transmission	R/H transmission	L/H transmission
Fore/aft cyclic	T	X	X	
Elevator	T	X	X	
Flaperon	T+	X	X	X_1
Rudder	S		X	
Lateral cyclic	S		X	
Excitation	S			X_2
Conversion	D	X	X	
Collective	T+	X	X	X.
RPM governor	T	X	X	
SCAS - Pitch	D	X	X	
Roll	D	X	X	
Yaw	S		X	
Force Feel -				
Pitch	S		X	
Roll	S		X	
Yaw	S		X	
Pitch Trim	S		X	
Emergency conversion	Motor			X
Heat exchanger blower	Motor		X	X
Landing gear	S			$X_{2,3}$

Remarks :

Type

T Tandem actuator

T+ Tan? m actuator with shuttle valve to permit PC, backup for PC,

D Dual actuator

S Single actuator

Subscripts:

1. Employed upon loss of PC,
2. Isolated from PC_3 upon loss of PC_2 or PC,
3. Pneumatic backup employed after loss of PC,, or PC_3.

Table III - Aircraft Instrumentation

(a) Propulsion System Measurements

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Fuel systems	Right engine	Total fuel was R5XX	R516	8 DMX	lb	100 ?	digital	Mass fuel flow
	Left engine	Total fuel was R511	R517	8 DMX	lb	100		Mass fuel flow
	Right engine	Fuel flow rate	R328	1 AMX	lbs/hr	10		Mass fuel flow
	Left engine	Fuel flow rate	R329	1 AMX	lbs/hr	10		Mass Fuel Flow
Torque system	Right ~~engine~~ XSMN	Torque (Simmonds Precision system)	M335	1 AMX	in.-lb	50 was 10	±2.5 V	Voltage output
	Left ~~engine~~ XSMAI	Torque (Simmonds Precision system)	M336	1 AMX	in.-lb	50		Voltage output
	Interconnect XSMU - X Shaft	Torque (Simmonds Precision system)	M337	1 AMX	in.-lb	50		Voltage output
Turbine speeds	Right engine	Gas producer speed (N_I)	R503	1 AMX	rpm	50		Tachometer generator
	Left engine	Gas producer speed (N_I)	R515	1 AMX	rpm	50		Tachometer generator
	Right engine	Power turbine speed (N_{II}) (Simmonds Precision system)	R338	1 AMX	rpm	10		Voltage output
	Left engine	Power turbine speed (N_{II}) (Simmonds Precision system)	R339	1 AMX	rpm	10	±2.5 V	Voltage output
Engine vibration	Right engine	Inlet case - fore and aft	A500	1 AMX	g	50	±5 V	Accelerometer (RMS detector)
		Inlet case - vertical	A502	1 AMX	g		∓5 V	Accelerometer (RMS detector)
		Inlet case - lateral	A501	1 AMX	g		∓5 V	Accelerometer (RMS detector)
	Left engine	Inlet case - fore and aft	A507	1 AMX	g		∓5 V	Accelerometer (RMS detector)
		Inlet case - vertical	A514	1 AMX	g		∓5 V	Accelerometer (RMS detector)
		Inlet case - lateral	A508	1 AMX	g	50	±5 V	Accelerometer (RMS detector)
Pylon temperatures	Right system	1. Transmission compartment ambient 2. Blower air - outlet of heat exchanger 3. Transmission oil into cooler 4. Transmission oil into cooler 5. Transmission case surface 6. Transmission case surface	T506	1 AMX*	°F	100	6 mV	Temperature scanner

*Thermocouples go through a switch and appear as a single channel at the program board. One for each pylon and one for the fuselage. Sensitivities are 3 mV -100°F.

Table III - Aircraft Instrumentation

(b) Propulsion Systems Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
	Right system (continued)	7. Transmission case surface 8. Transmission case surface 9. ECU bleed air to swivel 10. PC_2 hyd reservoir pressure port 11. Engine oil outlet 12. Turbine inlet (Lycoming T-7 harness) PC_2 hyd cooler fluid in PC_2 hyd cooler fluid out ECU cooler bleed air in Fuel Engine inlet housing Engine accessory housing Engine axial compressor Engine centrifugal compressor Engine compressor diffuser Engine exhaust diffuser Engine ignition unit Engine fuel control Engine igniter solenoid valve Engine air bleed control Engine thermocouple harness connector Starter generator N_I techometer generator Engine compartment above inlet Tail pipe fairing compartment						
	⚠1							

Table III - Aircraft Instrumentation

(c) Propulsion Systems Measurements (cont)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
	Left system 2 (in a triangle)	1. Transmission compartment ambient 2. Blower air outlet of heat exchanger 3. Transmission oil into cooler 4. Transmission oil out of cooler 5. Transmission case surface 6. Transmission case surface 7. Transmission case surface 8. Transmission case surface 9. PC_1 hyd reservoir pressure port 10. PC_3 hyd reservoir pressure port 11. Engine oil outlet 12. Turbine inlet (Lycoming T-7 harness) PC_1 hyd cooler fluid in PC_1 hyd cooler fluid out PC_3 hyd cooler fluid in PC_3 hyd cooler fluid out Inlet temperature 0° position ✓ Inlet temperature 120° position ✓ Inlet temperature 240° position ✓ Transmission case surface Transmission case surface Transmission case surface	T513 was	1 AMX* 4 @	°F 3, 6, 12	100 Rods	6 mV	Temperature sensor

* Thermocouples go through a switch and appear as a single channel at the program board. One for each pylon and one for the fuselage. Sensitivities are 3 mV -100°F.

Table III - Aircraft Instrumentation

(d) Propulsion Systems Measurements (cont)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pylon pressures	Right system △3	Atmospheric (static ref)	P505	1 PSF	psi	100	±10 mV	Pressure Transducer
		Transmission compartment static	P504	1 PSF	psi	100	±10 mV	Pressure Transducer
	Left system △4	Atmospheric (static ref) Transmission compartment static Engine compartment air scoop (Total and static - 5 ports) Engine inlet bell mouth (Total and static - 39 ports) Engine tail pipe (Static - 4 ports)	P512	1 PSF*	psi	100	±10 mV	Scanivalve
		Engine inlet bell mouth High frequency @ 160°	P518	1 AMX	psi	100	50 mV	Transducer
		Engine inlet bell mouth High frequency @ 320°	P519	1 AMX	psi	100	50 mV	Transducer

△1 These 19 measurements may not be required after cooling and temperature surveys are documented

△2 These 10 measurements may not be required after cooling, temperature, and inlet surveys are documented

△3 These 2 measurements may not be required after temperature and cooling surveys are documented

△4 These 52 measurements may not be required after cooling, temperature, inlet, and tail pipe surveys are documented.

*Thermocouples go through a switch and appear as a single channel at the program board. One for each pylon and one for the fuselage. Sensitivities are 3 mV ≈100°F.

Table III - Aircraft Instrumentation

(e) Airframe Load Measurements

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Right Wing	BL 0 0	Upper panel outer skin stress	S628	1 PSF	in.-lb	50	±5 mV	4-arm strain gage
		Lower panel outer skin stress	S629					
		Upper panel inner skin stress *	S609					
		Lower Panel inner skin stress *	S610					
	WS 22 0	Wing chord bending	B603					
		Wing beam bending	B600					
		Wing torque	M606				±5 mV	
	WS [illegible]6 0	Wing front spar shear (upper)	S630				±2.5 mV	
		Wing front spar shear (lower)	S631					
		Wing rear spar shear (upper)	S632					
		Wing rear spar shear (lower)	S633					
	WS 142 0	Wing front spar shear (upper)	S634					
		Wing front spar shear (lower)	S635					
		Wing rear spar shear (upper)	S636					
		Wing rear spar shear (lower)	S637					
Left Wing	WS 22 0	Left wing chord bending	B625					
		Left wing beam	B626					
		Left wing torque	M627					
Right horizontal stabilizer	BL +0.25	Beam bending	B260					
	BL -0.25	Beam bending	B261					
	BL -7.7	Beam bending	B262					
	BL 7.7	Chord bending	B263					
	BL 3.0	Torque bending	M266					
	BL 63.0	Chord bending	B265					
	BL 65.0	Beam bending	B264					
	BL 68.0	Torque	M267			50	±2.5 mV	
Right vertical stabilizer	WL 108.0	Chord bending	B271			100	±5 mV	
	WL 103.9	Beam bending	B270				±5 mV	
	WL 103.68	Torque	M273				±2.5 mV	
	WL 97.0	Chord bending	B269					
	WL 95.6	Beam bending	B268					
	WL 97.98	Torque	M272			100		
Right pylon								
Pylon conversion spindle		Beam bending	B165			50		
		Chord bending	B166	1 PSF	in.-lb	50	±2.5 mV	4-arm strain gage

* REDUNDANT GAGES INSTALLED IN THESE LOCATIONS

Table III - Aircraft Instrumentation

(f) Airframe Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pylon conversion actuator		Axial load	F611	1 PSF	lb	100	±10 mv	C-arm strain gage
Right pylon		Lower cowl outboard support strut axial load	F522			50	±10 mv	
		Lower cowl inboard support strut axial load	F523					
Left pylon		Lower cowl outboard support strut axial load	F520					
		Lower cowl inboard support strut axial load	F521		lb	50		
Control surfaces								
Right flap	WS 25.0	Drive tube torque Beam bending	M612 B613		in.-lb	100		
Left flap		Drive tube torque Beam bending	M619 B618		in.-lb			
Right flaperon	WS 107.0	Control arm force Beam bending	F614 B615		lb in.-lb			
Left flaperon		Control arm force Beam bending	F621 B622		lb in.-lb			
Elevator								
Right elevator	BL 3.8 BL 49.5	Drive tube torque Beam bending	M275 B274		lb in.-lb			
Left elevator	BL 3.8 BL 49.5	Drive tube torque Beam bending	M279 B282	1 PSF	lb in.-lb	100	±10 mv	C-arm strain gage

Table III - Aircraft Instrumentation

Ig) Airframe Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Right rudder	WL 105.93 WL 118.76	Drive tube torque Beam bending	M276 B278	1 PSF	lb in.-lb	100	±10 mV	4-arm strain gage
Left rudder	WL 105.93 WL 118.76	Drive tube torque Beam bending	M277 B280	1 PSF	lb in.-lb			
Horizontal* Stabilizer		Incidence actuator force	F286	1 AMX	lb	100	±10 mV	
Left Pylon								
Pylon conversion spindle		Beam bending Chord bending	B190 B191	1 PSF 1 PSF	in.-lb. in.-lb.	50 50	±2.5 mV ±2.5 mV	
Pylon conversion actuator		[illegible]al Load	F638	1 PSF	lb	100	±50 mV	4-arm strain gage

* To be used at a later date.

Table III - Aircraft Instrumentation

(h) Airframe Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pilot flight controls								
Cyclic stick		Fore and aft force Lateral force	F330 F331	1 PSF	lb	10	±25 mV	4-arm strain gage
Right pedal		Force	F333					
Left pedal		Force	F334	1 PSF	lb	10	±25 mV	
Landing gear, right main								
Trunnion arm		Vertical bending	B333	1 AMX	in.-lb	50	±10 mV	
Oleo strut		Fore and aft bending Lateral bending	B354 B316		in.-lb		±10 mV	
Drag strut		Axial force	F303		lb		±23 mV	
Landing gear, left main								
Trunnion arm		Vertical bending	B310		in.-lb		±10 mV	
Oleo strut		Fore and aft bending Lateral bending	B311 B312		in.-lb		±10 mV	
Drag strut		Axial force	F313	1 AMX	lb	50	±25 mV	4-arm strain gage

Table III - Aircraft Instrumentation

(i) Airframe Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Nose gear								
Right trunnion		Vertical bending	B343	1 AMX	in.-lb	50	±10 mV	4-arm strain gage
Left trunnion		Vertical bending	B344					
Oleo strut		Fore and aft bending Lateral bending	B345 B346		in.-lb		±10 mV	
Drag strut		Axial force	F347	1 AMX	lb	50	±25 mV	4-arm strain gage

Table III - Aircraft Instrumentation

(j) Rotor Load Measurements

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Rotor blade	Sta 9.5	Leading edge stress	S145	1 PSF	psi	100	±10 mV	4-arm strain gage
		Trailing edge stress	S146					
Right rotor red blade	Sta 22.8	Beam bending	B120		in.-lb		±5 mV	
	Sta 52.5	Beam bending	B122				±25 mV	
		Chord bending	B123				±25 mV	
		Torque	M129				±25 mV	
	Sta 75.0	Beam bending	B124				±10 mV	
		Chord bending	B125				±10 mV	
	Sta 112.5	Beam bending	B126				±10 mV	
		Chord bending	B127				±5 mV	
		Torque	M128				±10 mV	
Left rotor red blade	Sta 22.8	Beam bending	B130				±5 mV	
	Sta 52.5	Beam bending	B132				±25 mV	
		Chord bending	B133				±25 mV	
		Torque	M139				±25 mV	
	Sta 75.0	Beam bending	B134				±10 mV	
		Chord bending	B135				±10 mV	
	Sta 112.5	Beam bending	B136				±10 mV	
		Chord bending	B137				±5 mV	
		Torque	M138		in.-lb		±10 mV	
Left rotor red blade	Sta 9.5	Leading edge stress	S147		psi		±10 mV	
		Trailing edge stress	S148				±10 mV	
Rotor hub								
Right red spindle	Sta 9.0	Beam bending	B112				±5 mV	
		Chord bending	B113		psi		±5 mV	
Right white spindle	Sta 9.0	Beam bending	B171		in.-lb		±5 mV	
		Chord bending	B172					
Right Green spindle	Sta 9.0	Beam bending	B173				±5 mV	
		Chord bending	B174	1 PSF	in.-lb	100	±5 mV	4-arm strain gage

Table III - Aircraft Instrumentation

(k) Rotor Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Left red spindle	Sta 9.0	Beam bending Chord bending	B114 B115	1 PSF	in.-lb	100	±5 mV	4-arm strain gage
Left white spindle	Sta 9.0	Beam bending Chord bending	B192 B193					
Left green spindle	Sta 9.0	Beam bending Chord bending	B194 B195	1 PSF	in.-lb	100	±5 mV	4-arm strain gage
RIGHT MAST		PARALLEL BENDING	B108	PSF	IN-lbs	100	± 5 mv	4-ARM STRAIN GAGE
		PERPENDICULAR BENDING	B109				± 5 mv	
		TORQUE	H107	PSF	IN-lbs	100	±2.5 mv	4 ARM STRAIN GAGE

R-

Table III - Aircraft Instrumentation

(1) Rotor Load Measurements (cont)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Left mast		Parallel bending	B140	1 PSF	in.-lb	100	±5 mV	4-arm strain gage
		Perpendicular bending	B141				±5 mV	
		Torque	M143				±2.5 mV	
					in.-lb			
Rotor pitch change links								
	Right	Red link axial force	F103		lb		±5 mV	
		White link axial force	F104					
		Green link axial force	F055					
	Left	Red link axial force	F060					
		White link axial force	F061					
		Green link axial force	F062					
Swashplate drive link								
	Right	Driver bending	B052					
	Left	Driver bending	B142	1 PSF	lb	100	±5 mV	4-arm strain gage

Table III - Aircraft Instrumentation

(m) Rotor Load Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Control boost actuators								
	Right pylon	Cyclic fore and aft axial force Lateral axial force Collective axial force	F162 F163 F164	1 PSF	lb	100	±5 mV	4-arm strain gage
	Left pylon	Cyclic fore and aft axial force Lateral axial force Collective axial force	F187 F188 F189	1 PSF	lb	100	±5 mV	4-arm strain gage

Table III - Aircraft Instrumentation

(n) Position Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Airframe								
Flaps and flaperons	Right flap	Position measurement	D617	1 AMX	deg	10	±3 mV	Rotary potentiometer
	Left flap		D620					
	Right flap-eron		D616					
	Left flaperon		D623					
Elevator	Right elevator		D281					
Rudder	Right rudder		D284					Rotary potentiometer
Main landing	Right actuator		D317		deg			Cable potentiometer
	Oleo extension		D305		in.			
	Left actuator		D314		deg			
	Oleo extension		D315		in.			
Nose landing gear	Actuator		D348		deg			
	Oleo extension		D349		in.			
	Steering		D350		deg			Cable potentiometer
Horizontal* Stabilizer	Incidence actuator		D287		deg			Linear potentiometer
Ailerons	Right		D645		deg			
	Left	Position measurement	D646	1 AMX	deg	10	±3 mV	Linear potentiometer

* Tc

Table III - Aircraft Instrumentation

(o) Position Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
<u>Pilot controls</u>								
Cyclic stick	Fore and aft Lateral	Position measurement	D021 D022	1 AMX	deg	10	±3 V	Rotary potentiometer
Power lever			D023					
Rudder pedals			D024					
Fuel Control Lever	Right Left		D509 D510					
Flap controls	Flap lever		D309		deg	10		Rotary potentiometer
SCAS system	Fore and aft Lateral Directional		D306 D307 D308		in. in. in.	50 50 50		Linear potentiometer
Diff. cyc. washout act. pos.			D318		in.	10		Linear potentiometer
<u>Rotor positions</u>								
Hub spring motion	Right - fore and aft Right - lat. Left - fore and aft Left - lat.	Position measurement	D156 D157 D181 D182	1 AMX	deg deg	10	±3 V	LVDT LVDT

3

Table III - Aircraft Instrumentation

(p) Position Measurements (cont.)

A~	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Gimbal trunnion flapping	Right rotor Left rotor	Position measurement	D110 D144	1 AMX	deg	10 10	±3 V	Rotary potentiometer
Red blade feathering	Right rotor Left rotor		D111 D066		deg	10 10		Rotary potentiometer
Collective motion	Right act. Left act.		D158 D183		in.	10		Linear potentiometer
Swashplate motion	Right - fore and aft Right - lat. Left - fore and aft Left - lat.		D159 D160 D184 D185		in.	10		Linear potentiometer
Conversion motion	Right pylon Left pylon	Position measurement	D161 D136	1 AMX	deg deg	10 10	±3	Rotary potentiometer Rotary potentiometer
Rotor azimuth	Right rotor Left rotor	One per rev 512 per rev One per rev 512 per rev	R018 R053 R058 R059	1 DMX *1 FM 1 DMX *1-FM	blip blip blip blip	digital digital digital digital		Photo cell encoder Photo cell encoder Photo cell encoder Photo cell encoder

DMX also

* Pallet has 40x80 connector for line drivers; blip data. 512P also multiplexed @ lowest subcom giving location at about every 60° of rotor azimuth (random location based on Δt = 50SPS sam rate). FM track T/R also

Table III - Aircraft Instrumentation

(q) Miscellaneous Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Aircraft state measurements								
Airspeed	Nose boom	Pitot port	P002	1 AMX	psi	10	±5 V	Pressure transducer
Altitude		Static port Radar altimeter	P342 D327		psi feet		~~±5 V~~ 0-40 V	Pressure transducer Recorder output
Outside air temperature		Temperature probe	T322		°F		3 mV	Total air temperature system
Relative wind angles		Angle of attack	D008		deg		±3 V	Government-furnished equipment
	Nose boom	Angle of sideslip	D007			10	±3 V	Government-furnished equipment
Aircraft attitude		Roll Pitch Yaw	D009 D010 D011		 deg	10	±3 V ±3 V ±3 V	Attitude gyro Attitude gyro Attitude gyro
Aircraft angular rates		Roll Pitch Yaw	V012 V013 V014		deg/sec deg/sec deg/sec	 10	±2.5 V ±2.5 V ±2.5 V	Rate gyro Rate gyro Rate gyro
Vertical acceleration	Aircraft cg		A352	1 AMX	g	10	±5 V	Servo accelerometer
Aircraft system monitors								
Hydraulic system	Right pylon Left pylon Left pylon	Pressure #2 Pressure #1 Pressure #3 (standby)	P153 P178 P149	1 PSF 1 PSF 1 PSF	psi psi psi	100 100 100	±25 mV ±25 mV ±25 mV	Pressure transducer Pressure transducer Pressure transducer

signal input limited to ±100

Table III - Aircraft Instrumentation

(r) Miscellaneous Measurements (cont)

Are-	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Electrical system	Right	Dc generator - potential	E154	1 AMX	volt	100	0-28 V	
		Dc generator - current	E155		amp	100	0-50 mV	Shunt
	Left	Dc generator - potential	E179		volt	100	0-28 V	
		Dc generator - current	E180		amp	100	0-50 mV	Shunt
Fuel system	Right	Quantity	R320		lb	10	±25 mV	Recorder output
	Left	Quantity	R321		lb	10	±25 mV	Recorder output
Temperature	Right wing, left wing, and fuselage	Thermocouples	T351	1 AMX*	°F	100	3 mV	Temperature scanner
Oil pressure	Right engine	Pressure	P323	1 PSF	psi	10	±10 mV	Pressure transducer
	Left engine	Pressure	P324		psi	10		Pressure transducer
	Right transmission	Pressure	P325		psi	10		Pressure transducer
	Left transmission	Pressure	P326		psi	10		Pressure transducer
Aircraft Accelerations								
Aircraft center of gravity	Fore and aft	Accelerations	A301		g	50		Strain gage accelerometer
	Lateral		A300			50	±10 mV	
	Vertical		A005			50	±25 mV	
Pylons	Right - fore and aft		A150			100		
	Right - lat.		A151					
	Right - vert.		A152					
	Left - fore and aft		A175					
	Left - lat.		A176					
	Left - vert.	Accelerations	A177	1 PSF	g	100	±25 mV	Strain gage accelerometer

* 1 CHAN AMX (Temp switch) temp ref 3 mV ≈100°F

Signal input limited to ±100

Table III - Aircraft Instrumentation

(s) Miscellaneous Measurements (cont.)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Cockpit - pilot	Lateral	Accelerations	A302	1 PSF	g	50	±25 mV	Strain gage accelerometer
	Vertical		A019					
Cockpit - copilot	Lateral		A304					
	Vertical	Accelerations	A020	1 PSF	g	50	±25 mV	Strain gage accelerometer
Voltage sense	RR1	J-Box Signal Power Supply Voltage	E072	1 AMX	Volts	10	0-10V	Power Supply
	RR2		E073					
	RP1		E196					
	RP2		E197					
	RW1		E647					
	RW2		E648					
	LR1		E074					
	LR2		E075					
	LP1		E198					
	LP2		E199					
	LW1		E649					
	CP1		E369					
	CP2		E370					
	CP3		E371					
	CAB1		E373					
	N1		E372					
	RNG 1		E374					
	LNG1		E375					
	EMP1		E298					
	EMP2	J-Box Signal Power Supply Voltage	E299	1 AMX	Volts	10	0-10V	Power Supply
Calibration Voltage	RMDU #1	Calibration Voltage	E367	1 AMX	Volts	10	0-10V	Power Supply
	RMDU #2	Calibration Voltage	E368	1 AMX	Volts	10	0-10V	Power Supply

Table IV.- Wind-Tunnel Data Requirements

MEASUREMENT #	DESCRIPTION	INPUT TSP	~~[illegible]~~ PCM Word	OGR	CRO	HS	TCS	DAS	P-P	DPM	OBS	DAC	
B122	Right Bld Beam 52.5		B1-10		2	1		29	1			A6	Loads Panel
B132	Left " " "		B1-8			2		30	2			A4	"
B123	Right " Chord "		B1-20		6	3		28	3			A10	
B133	Left " " "		B1-9			4			4			A5	
F103	Right Pitch Link		B1-45			5		31	5			A24	Loads Panel
F060	Left " "		B1-21		3	6			6			A11	"
B165	Right Conv Spindle ~~Beam~~		B1-57			7			7			A27	"
B190	Left " " "		B2-54			8			8			A29	"
B166	Right " " Chord		B2-57			9			9			A30	
B191	Left " " "		B1-55			10			10			A26	
F611	Right " Actuator Load		B1-7			11			11			A3	
F636	Left " " "		A1-5			12			12			C1	
B112	Right Yoke Beam 9.0		B1-48		1	13			13			A25	
B114	Left " " "		B1-15			14			14			A7	
B113	Right " Chord "		B1-34		5	15			15			A18	Loads Panel
B115	Left " " "		B1-16			16		27	16			A8	"

Table IV.- (Continued)

MEASUREMENT #	DESCRIPTION	INPUT TSP	PCM Word	OGR	CRO	HS	TCS	DAS	P-P	DPM	OBS	DAC	
B109	Right Lerp Mast Bending		A1-21			17			17			E4	Load Panel
B141	Left " " "		B1-18			18			18			A9	"
M107	Right Mast Torque		B1-6			19		14	19	3		A2	"
M143	Left " "		B1-5			20		15	20	2		A1	"
D156	Right F/A Flapping	T104				21		22	21				AC Cons
D181	Left " "	T122				22		23	22				"
D157	Right Lat "	T101				23		24	23				"
D182	Left " "	T119				24		25	24				"
B656	Right Wing Beam 2Z	T107, 108, 109				25	1	4	25				
B626	Left " " "	T125, 126, 127				26	2	5	26				
B655	Right " Chord "	T110, 111, 112				27	3	6	27				
B625	Left " " "	T128, 129, 130				28	4	7	28				
M657	Right " Torsion "	T113, 114, 115				29	5	8	29				
M627	Left " " "	T131, 132, 133				30	6	9	30				
E747	Flaperon Exciter	T137				31		2					
E746	Collective "	T140				32		3					

Table IV.- (Continued)

MEASUREMENT #	DESCRIPTION	INPUT TSP	~~[illegible]~~ PCM Word	OGR	CRO	HS	TCS	DAS	P-P	DPM	OBS	DAC	
A150	Right Pylon F/A Accel.		B1-37			33		16				A19	
A175	Left " " "		B1-30			34		17				A15	
A151	Right " Lat "		B1-38			35		18				A20	
A176	Left " " "		B1-31			36		19				A16	
A152	Right " Vert "		B1-39			37		20				A21	
A177	Left " " "		B1-32			38		21				A17	
RSFAA	Right Strut F/A "	T004, 005,006				39	7	10					
LSFAA	Left " " "	T010, 011,012				40	8	11					
RSLAA	Right " Lat "	T001, 002,003				41	9	12					
LSLAA	Left " " "	T007, 008,009				42	10	13					
B262	Right Horiz. Beam 8.0		B1-58			43		26	31			A28	
B259	Left " " "		B2-60			44			32			A32	
B263	Right " Chord "		B2-58			45			33			A31	
F052	Right Swash Plate Driver		B1-44			46			34			A23	
F142	Left " " "		B1-24			47			35			A12	
F162	Right F/A [illegible]		B1-40			48			38			A22	

Table IV.- (Continued)

MEASUREMENT #	DESCRIPTION	INPUT TSP	PCM Word	OGR	CRO	HS	TCS	DAS	P-P	DPM	OBS	DAC	
F187	Left F/A Cyc Act Load		B1-27			49			39			A13	
F163	Right Lat " "		A1-29			50			40			C5	
F188	Left " " "		B1-28			51			41			A14	
F164	Right Collective " "		B1-19			52			42			B1	
F189	Left " " "		B1-29			53			43			B2	
B120	Right Blade Beam 22.8		A1-12			54			36			C2	
B130	Left " " "		B1-43			55			37			B5	
D158	Right Collective Pitch		B4-82			56						B13	AC Cons.
D183	Left " "		B3-79			57						B10	
D157	Right F/A cyclic		B5-82			58						B15	
D184	Left " "		B4-79			59						B12	
D160	Right Lat "		A2-72			60						C6	AC Cons.
M266	Right Horiz Torsion 8.0		B1-59									E6	BNC 1
B124	Right Blade Beam 75		B1-35									B3	BNC 2
B125	Left " Chord "		B1-36									B4	BNC 3
B126	Right " Beam 112		B1-16									C3	BNC 4

Table IV.- (Continued)

MEASUREMENT #	DESCRIPTION	INPUT TSP	PCM Word	OGR	CRO	HS	TCS	DAS	P-P	DPM	OBS	DAC	
D185	Left Lat Cyc ..		B5-79									B14	AC Cons
	Shaker excitation												..
	Az Right ..					(✓)		(✓)					
	Az Left					(✓)		(✓)					
	NPR Right					(✓)		(✓)					CTR 1
	NPR Left					(✓)		(✓)					CTR 2
D021	F/A Stick pos		B1-78							1		B7	
D022	Lat " "		B2-78							4		B8	
D023	Power Lever "		B3-78							5		B9	
D024	Pedal "		B4-78							6		B11	

TABLE V: WIND-TUNNEL TEST RESPONSIBILITY

ITEM	PROJECT OFFICE			WIND-TUNNEL STAFF			CONTRACTOR		
	Respon-sibility	Review	Ap-roval	Respon-sibility	Review	Ap-roval	Respon-sibility	Review	Ap-roval
PLANNING									
Test Plan			X		X		X		
Instrumentation Plan									
aircraft			X		X		X		
wind tunnel		X		X				X	
Systems Safety Analysis			X		X		X		
Test Readiness Report		X				X		X	
HARDWARE									
Aircraft		X			X		X		
Wind Tunnel									
Remote control		X			X		X		
Interface		X		X				X	
fuel & hydraulics				X					
electrical							X		
instrumentation				X					
Data displays									
wind tunnel				X					
console							X		
OPERATIONS									
Operators				X			X		
Inspect. & Maint.							X		
Test Direction	X			X			X		
Consumables				X					
Data reduction									
Wind tunnel				X					
PCM tape							X		
REPORTING									
Failure & Maint.		X					X		
Incident/Accident		X		X			X		
Systems Safety Rept.		X				X	X		
Test Report			X		X		X		

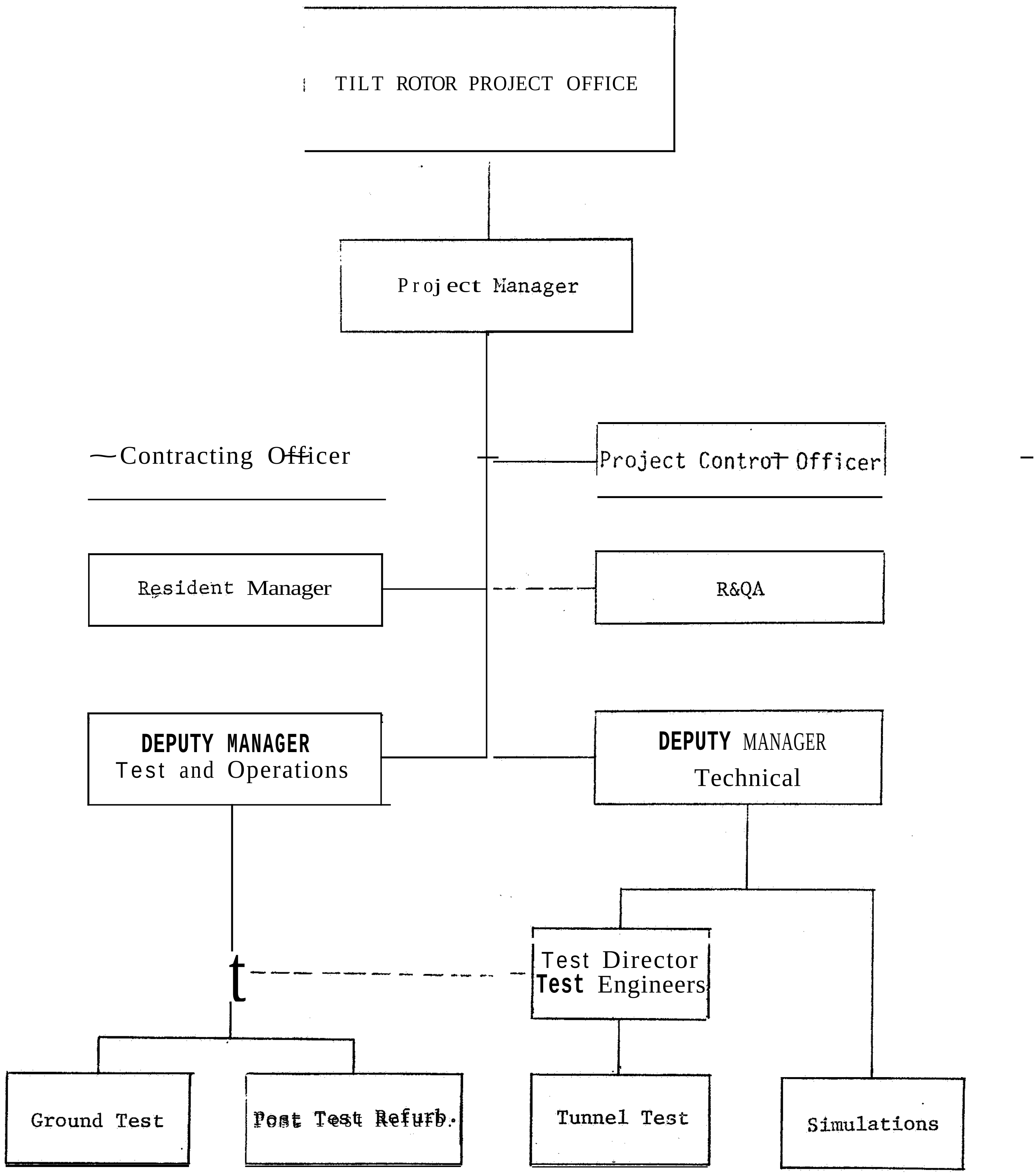


Figure 3-1.- Wind-tunnel test program management.

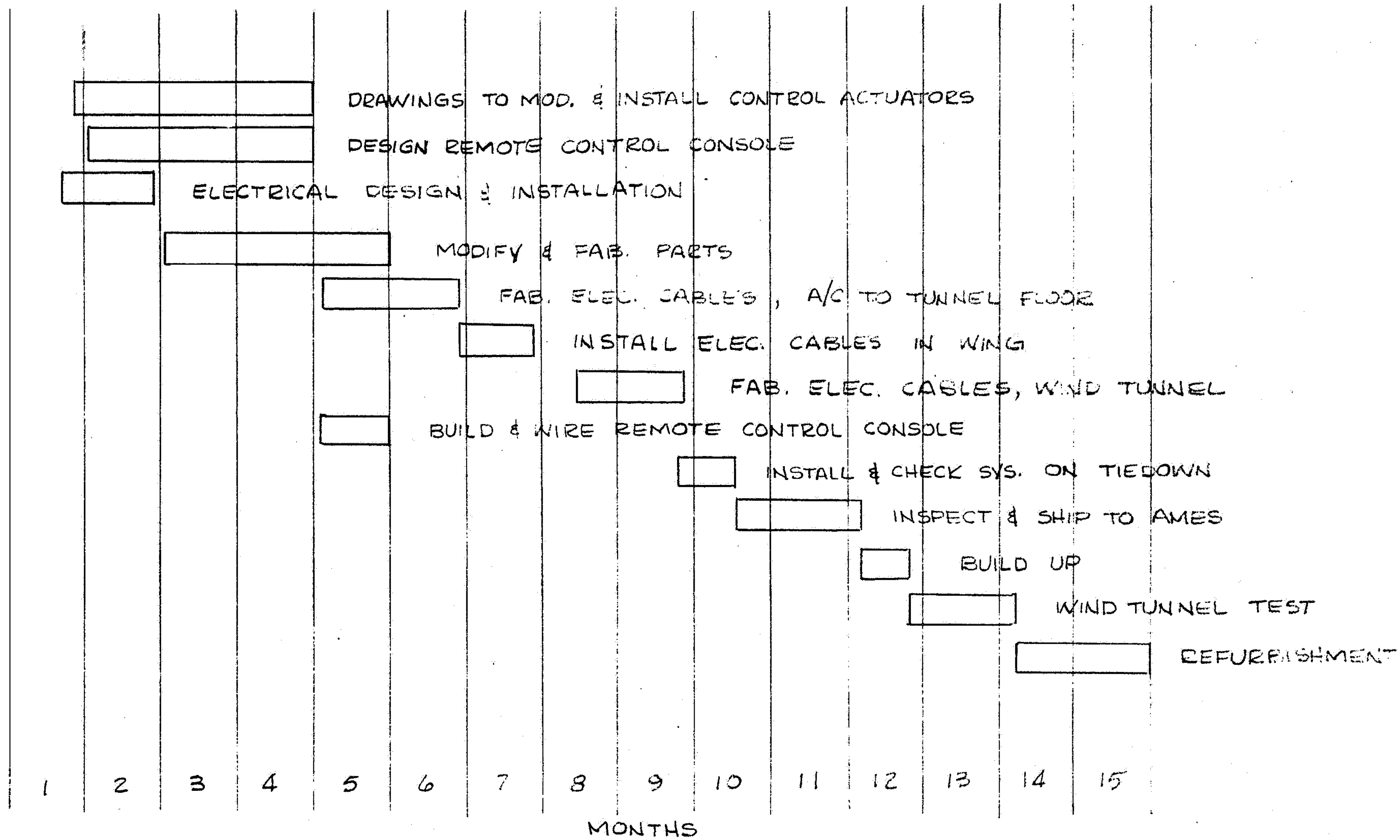


Figure 4-1 - Schedule for wind-tunnel test.

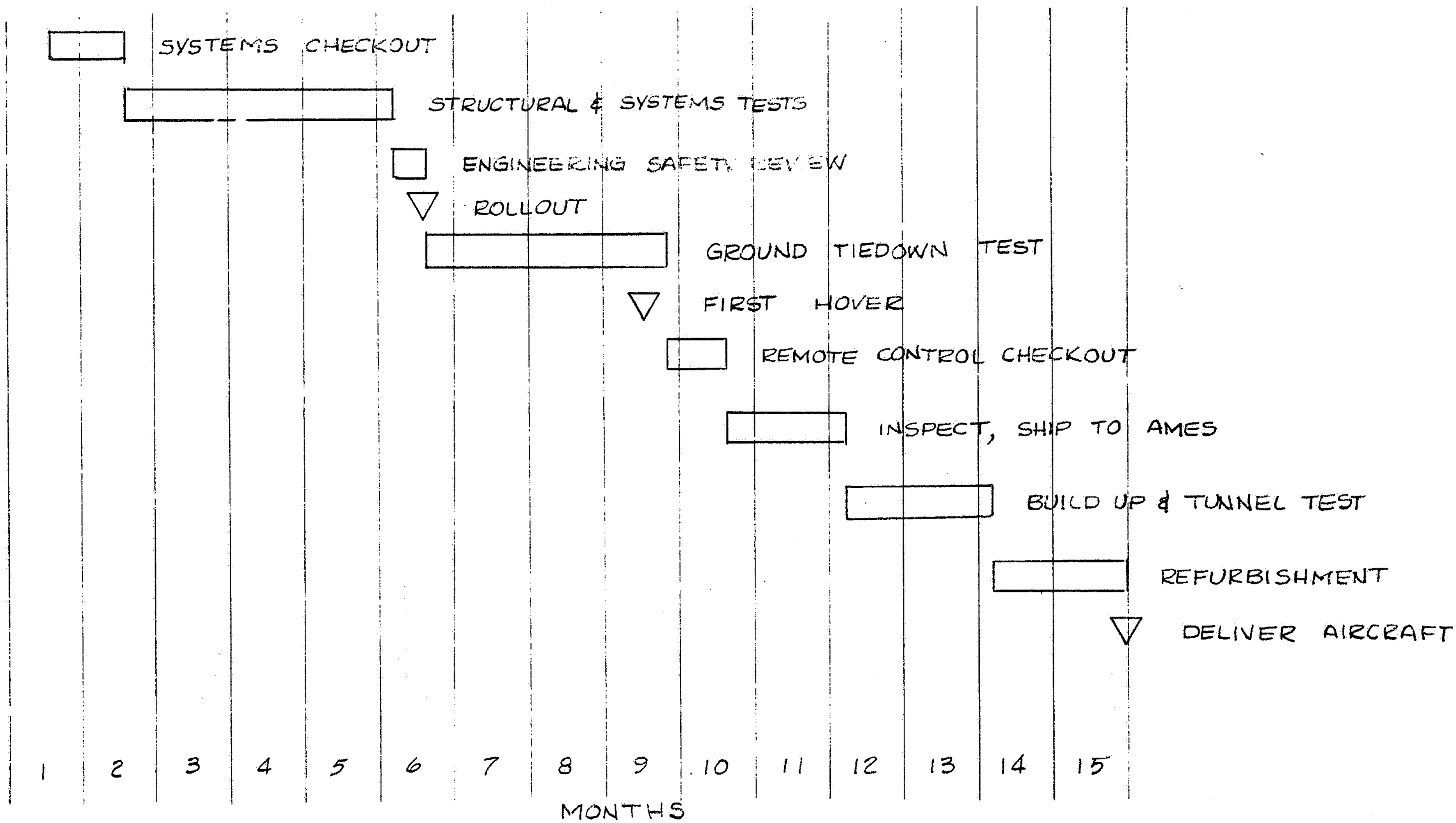


Figure 4-Z - Aircraft Schedule.

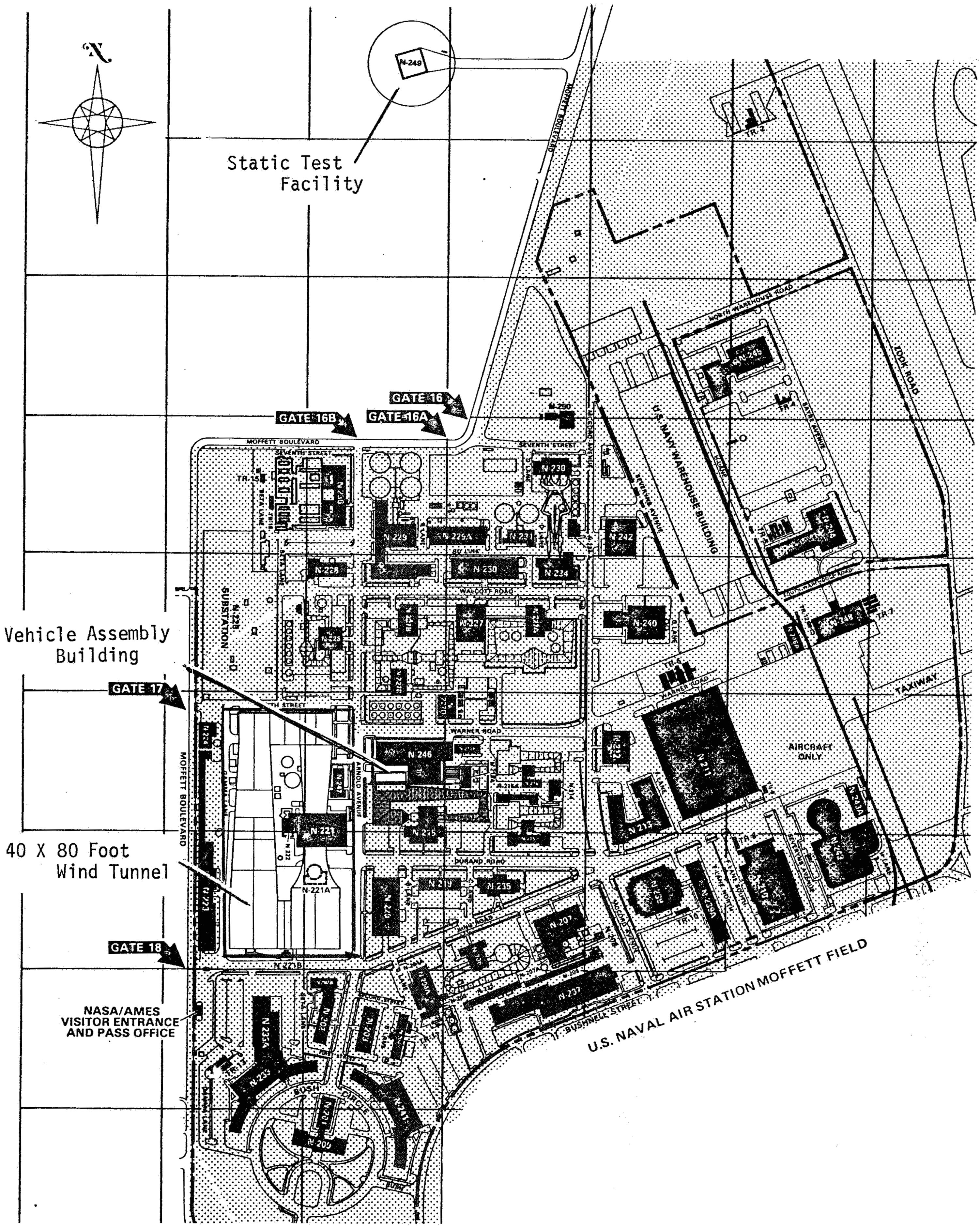
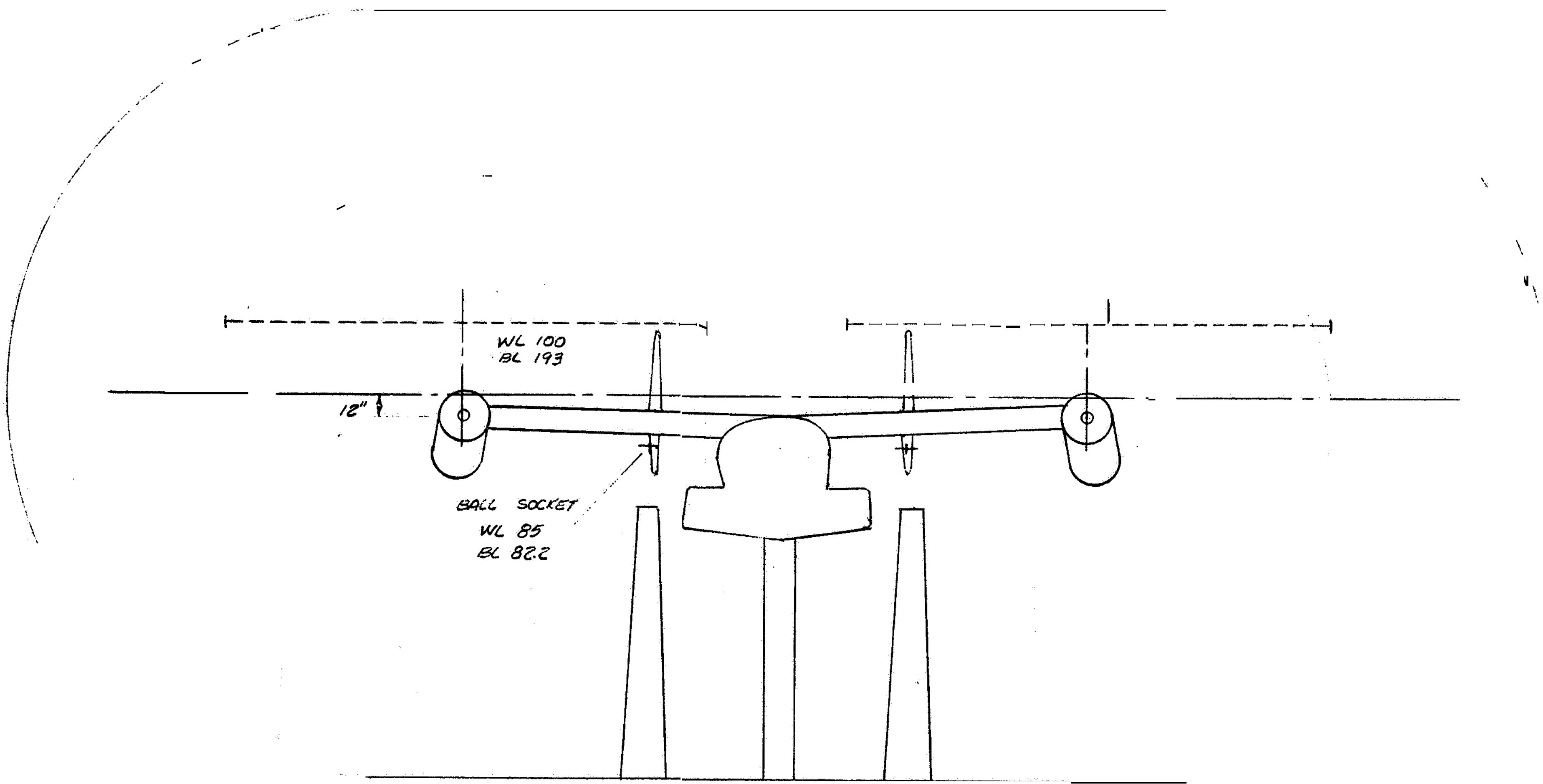
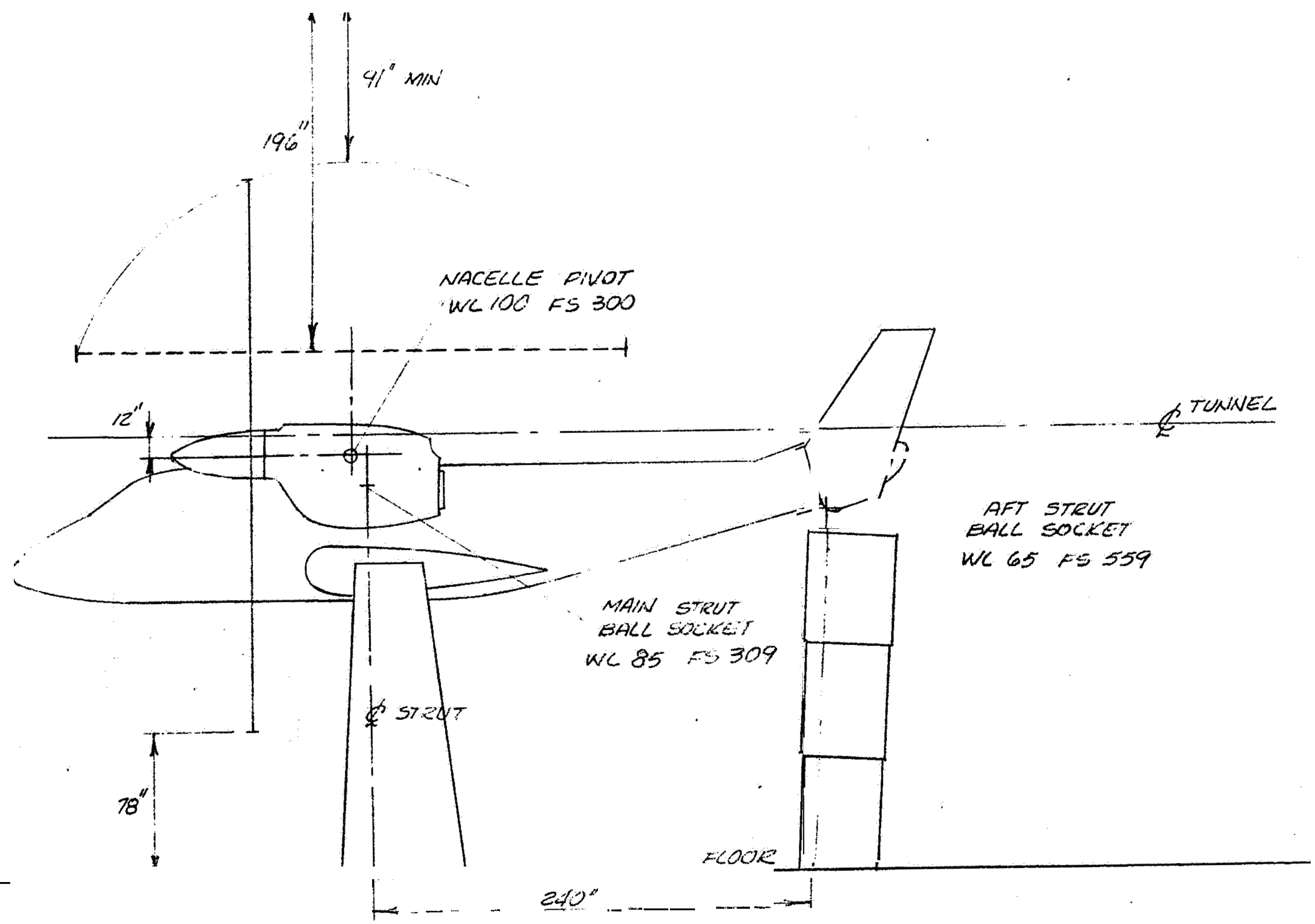


Figure 4-3 . — Ames Facilities for Assembly and Test



(a) Front view

Figure 4-4.- The XV-15 in the 40- by 80-Foot Wind Tunnel



(b) Side view

Figure 4-4. Concluded

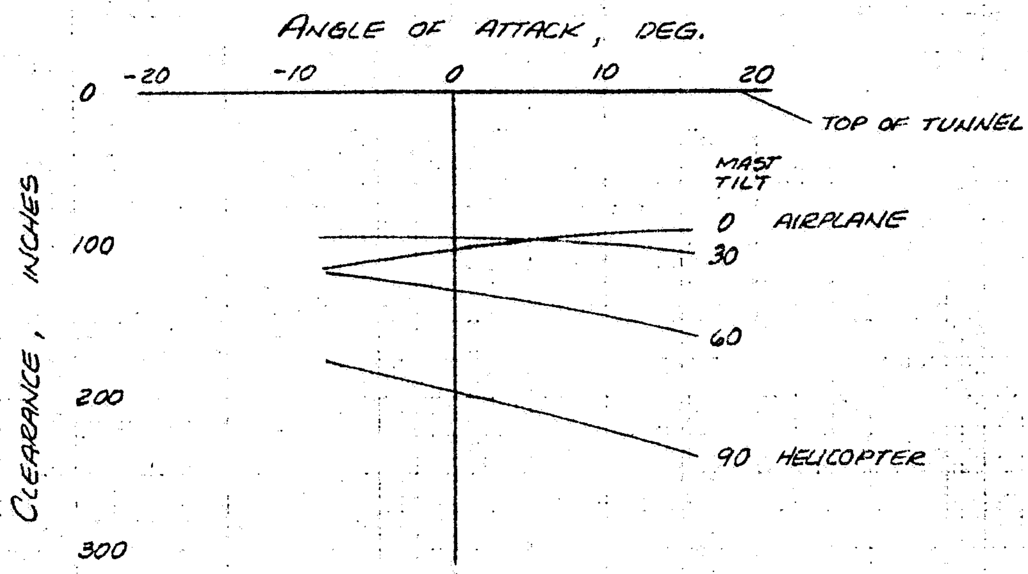


Figure 4-5.- Rotor/tunnel wall clearance for the XV-15 in the 40- by 80-Foot Wind Tunnel

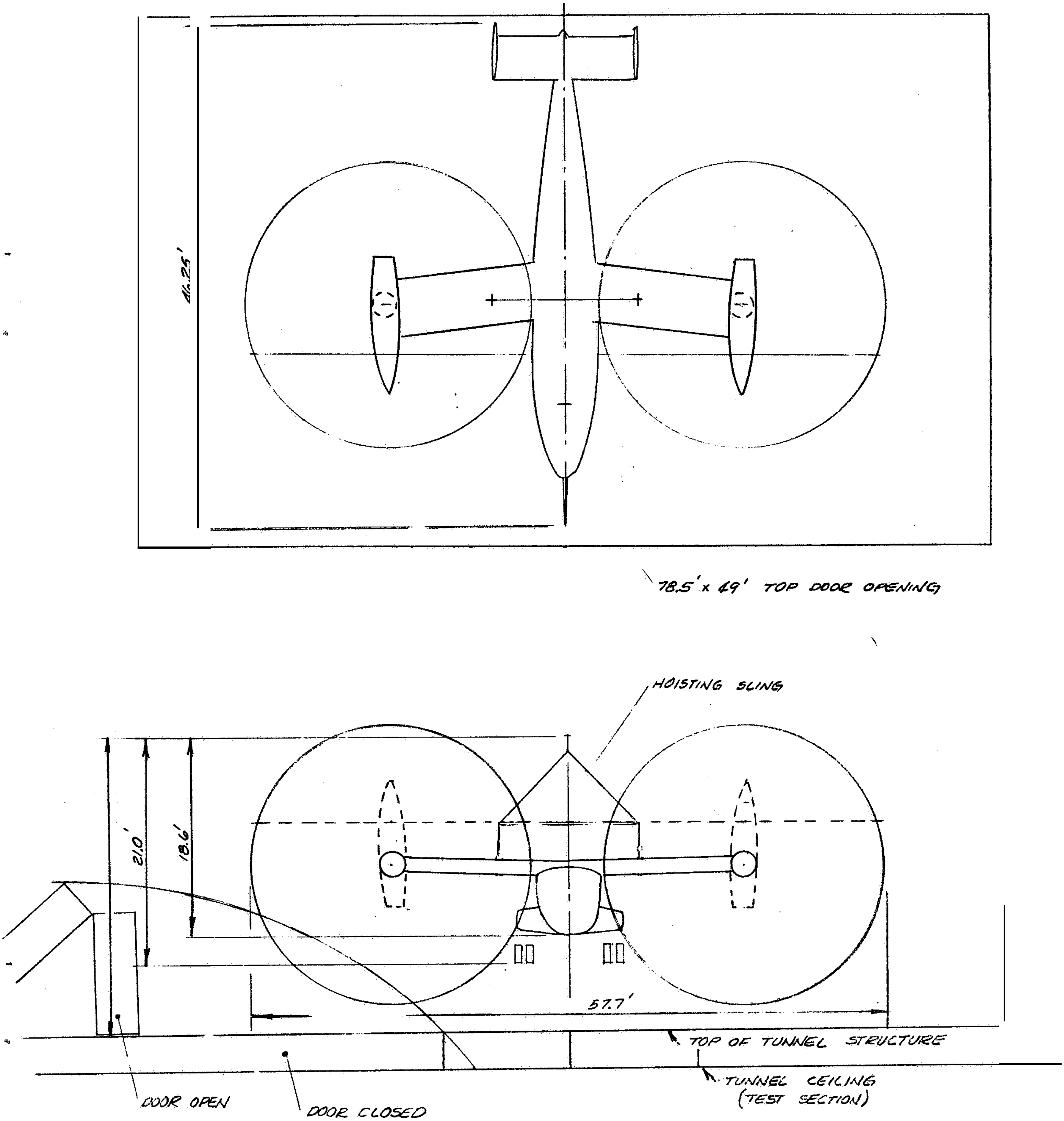


Figure 4-6.- Hoisting arrangement.

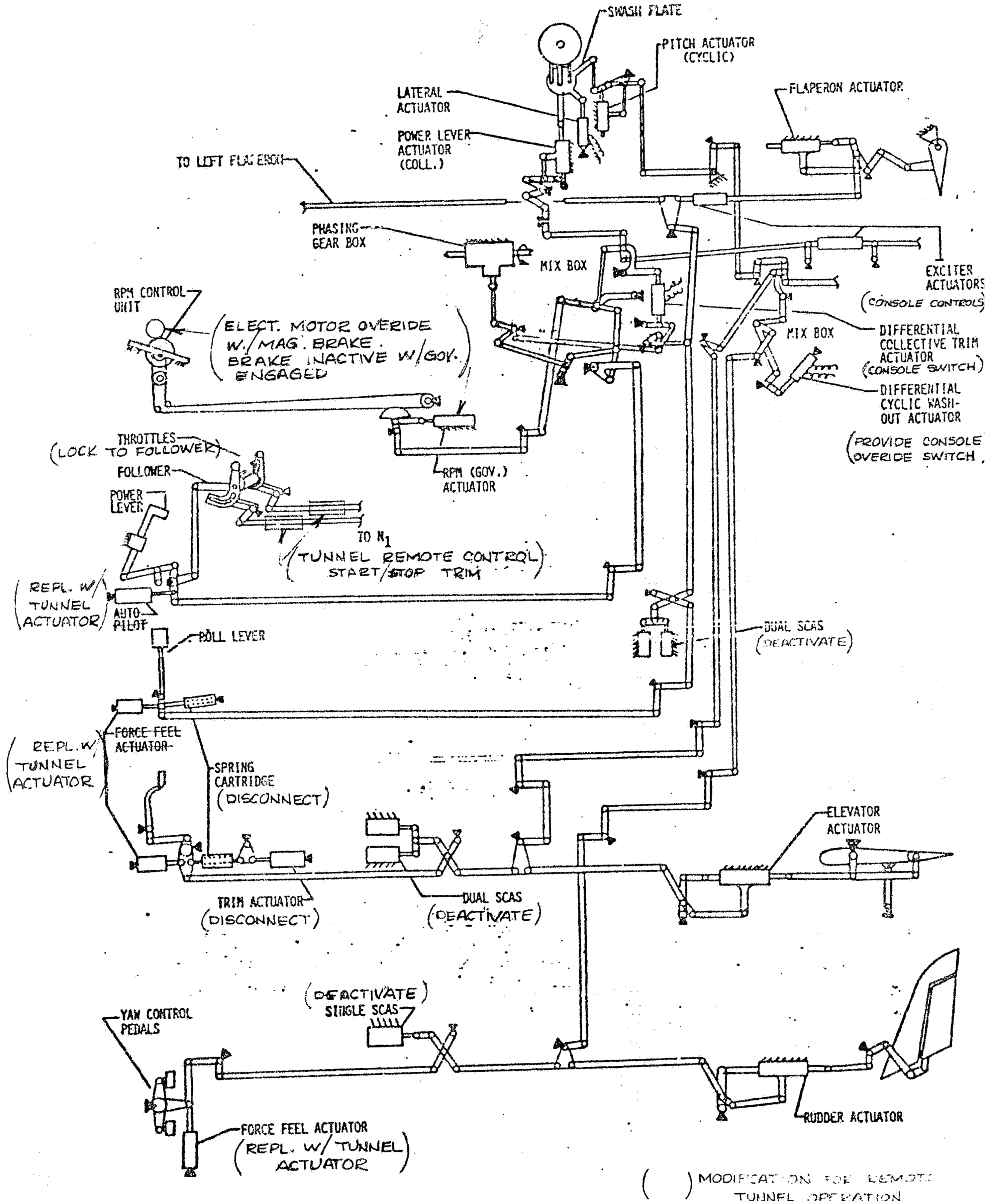
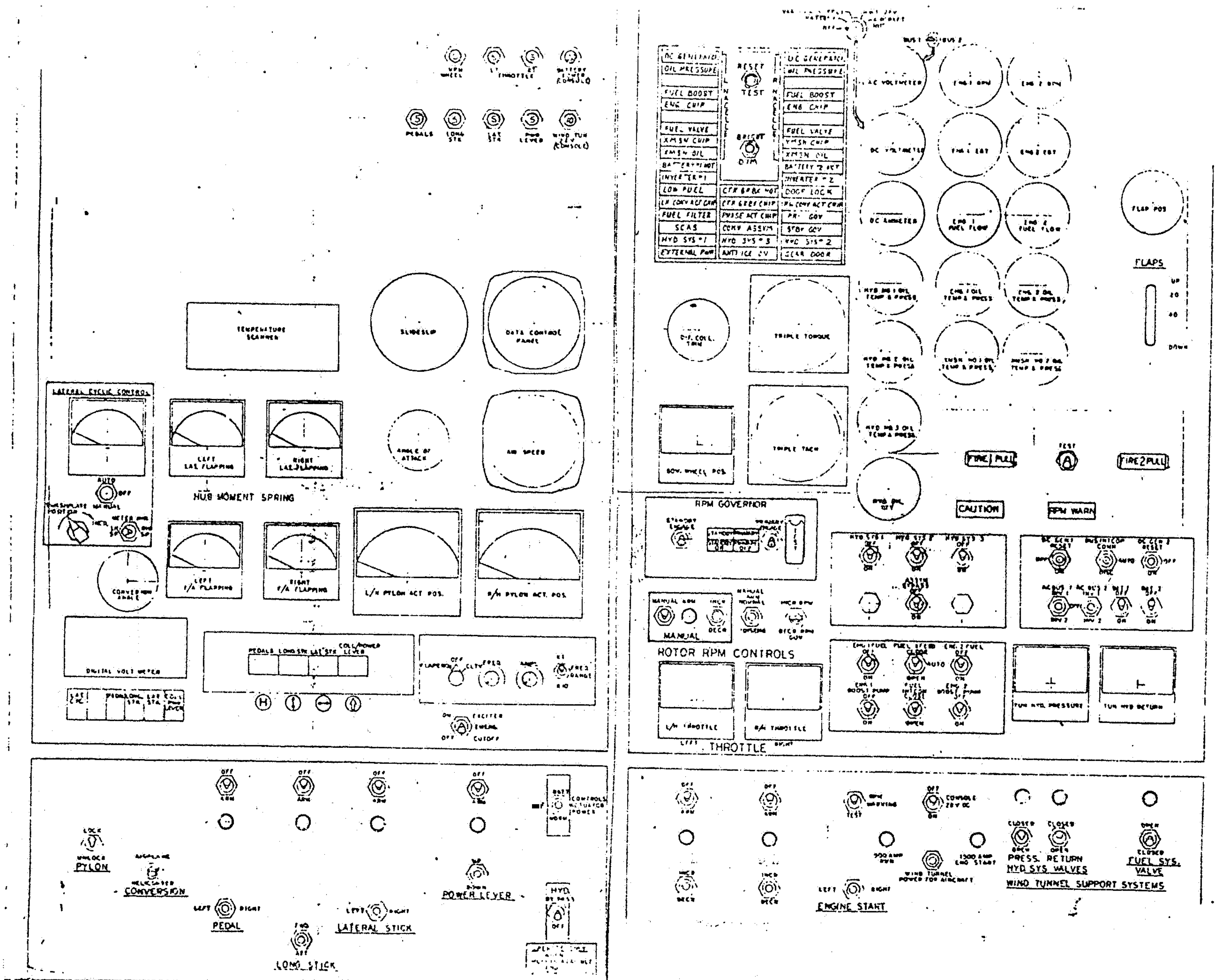


Figure **4-7.- Flight controls schematic.**



(a) Control panel

Figure 4-8.- Remote control console

(b) Loads panel

Figure 4-8.- Concluded.

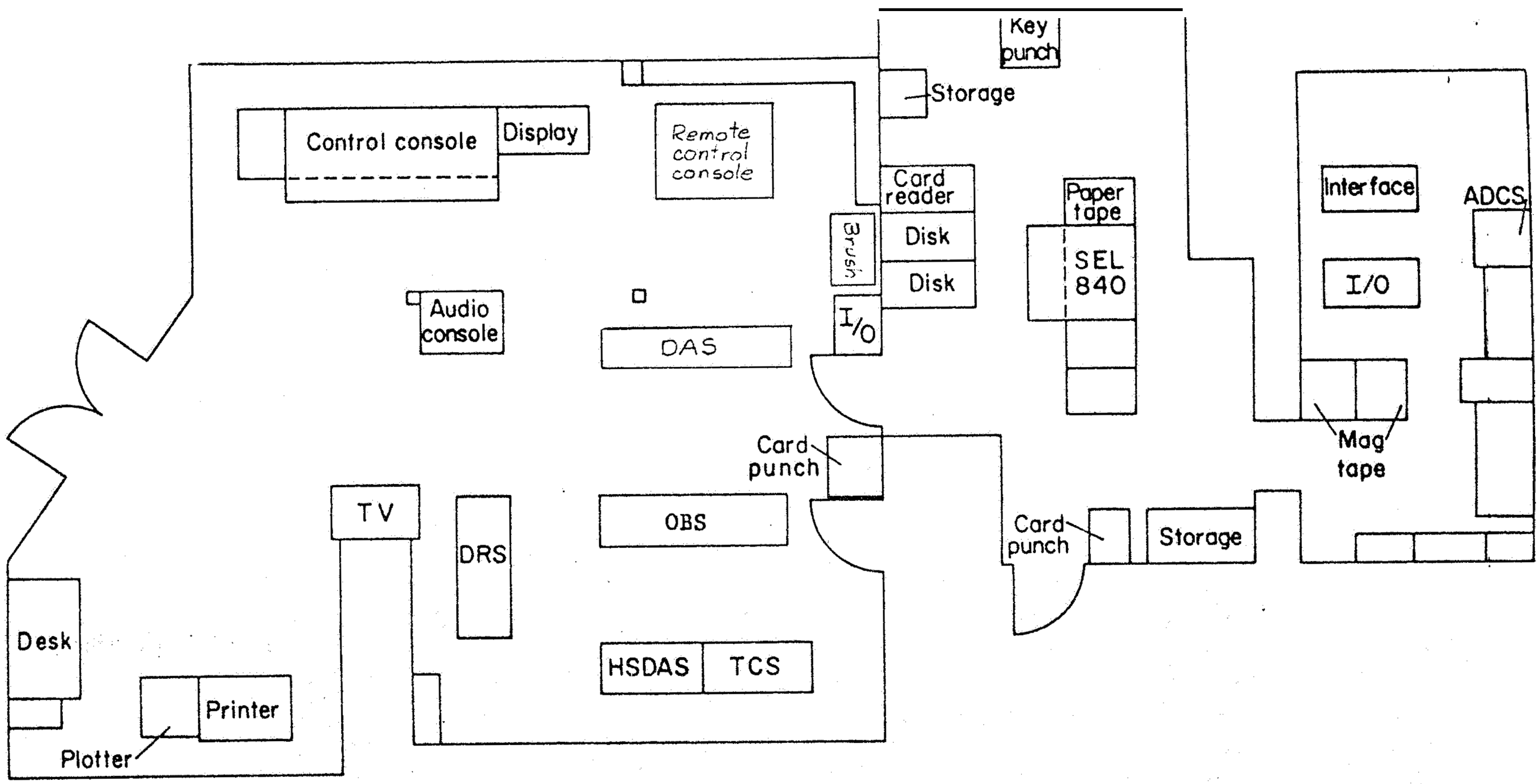


Figure 4-9 . — Wind-Tunnel Control Room

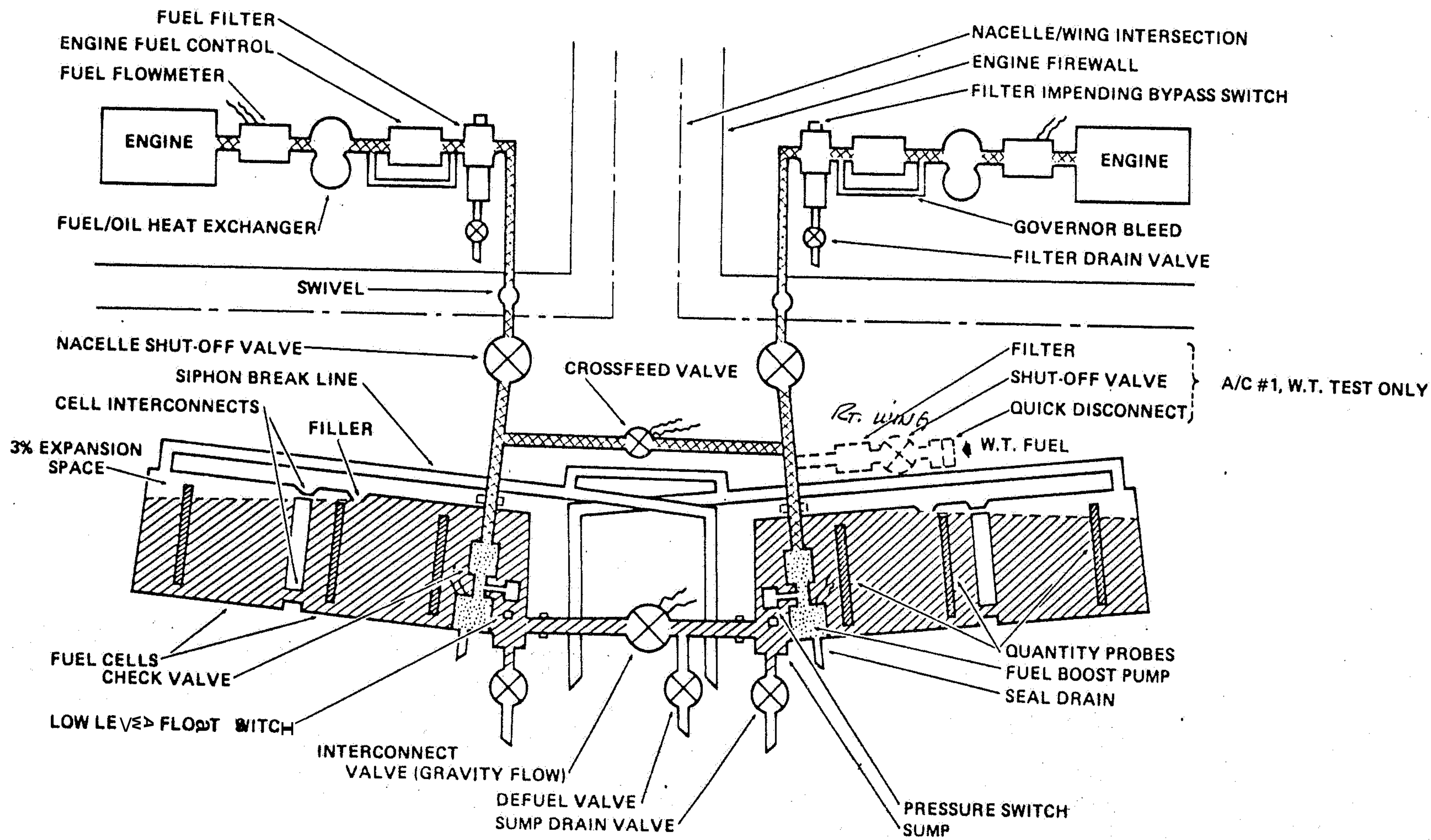


Figure 4-10. — Fuel System Schematic

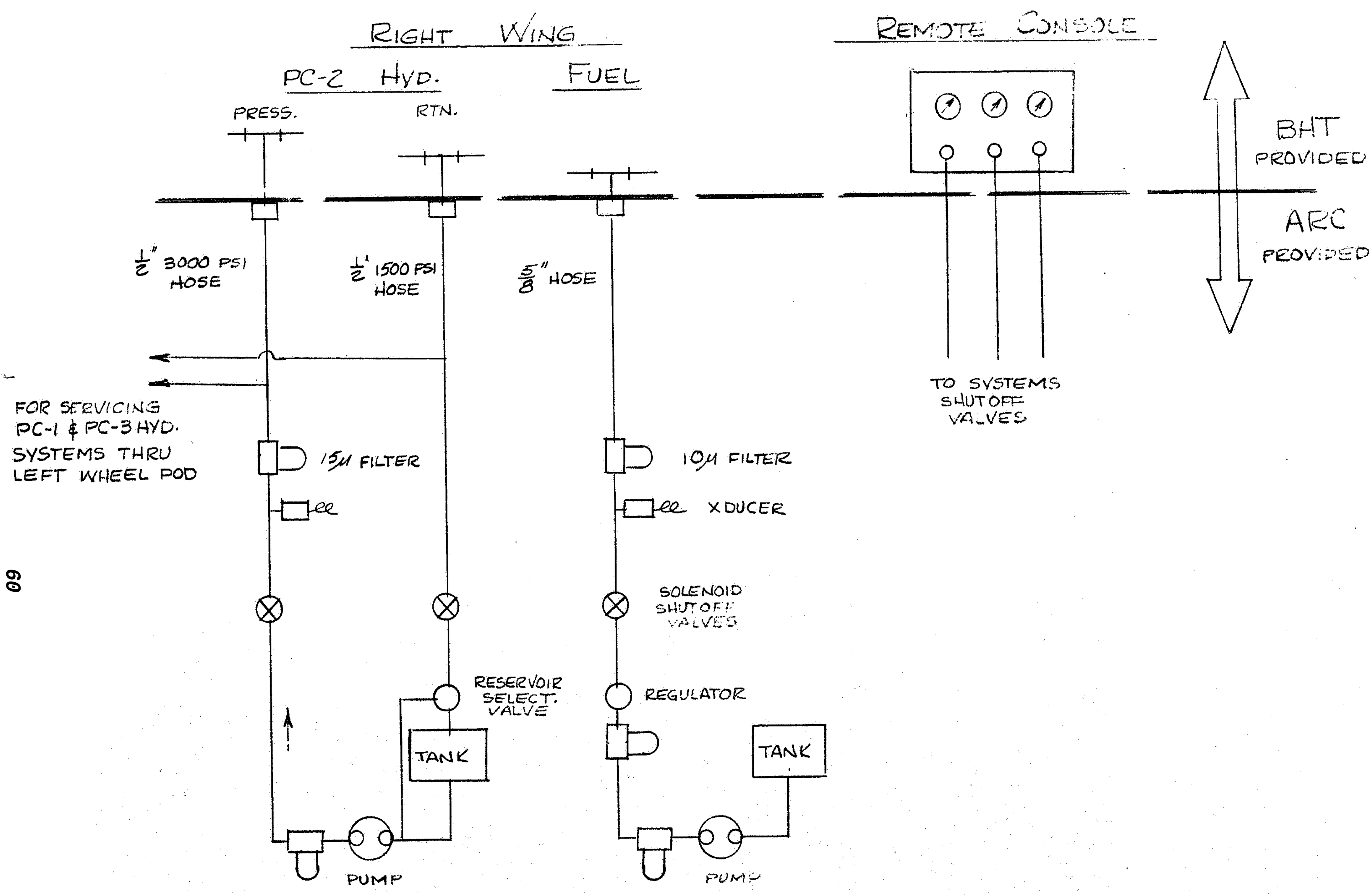


Figure 4-11 . — Aircraft/Wind Tunnel Interface, Hydraulic & Fuel Systems

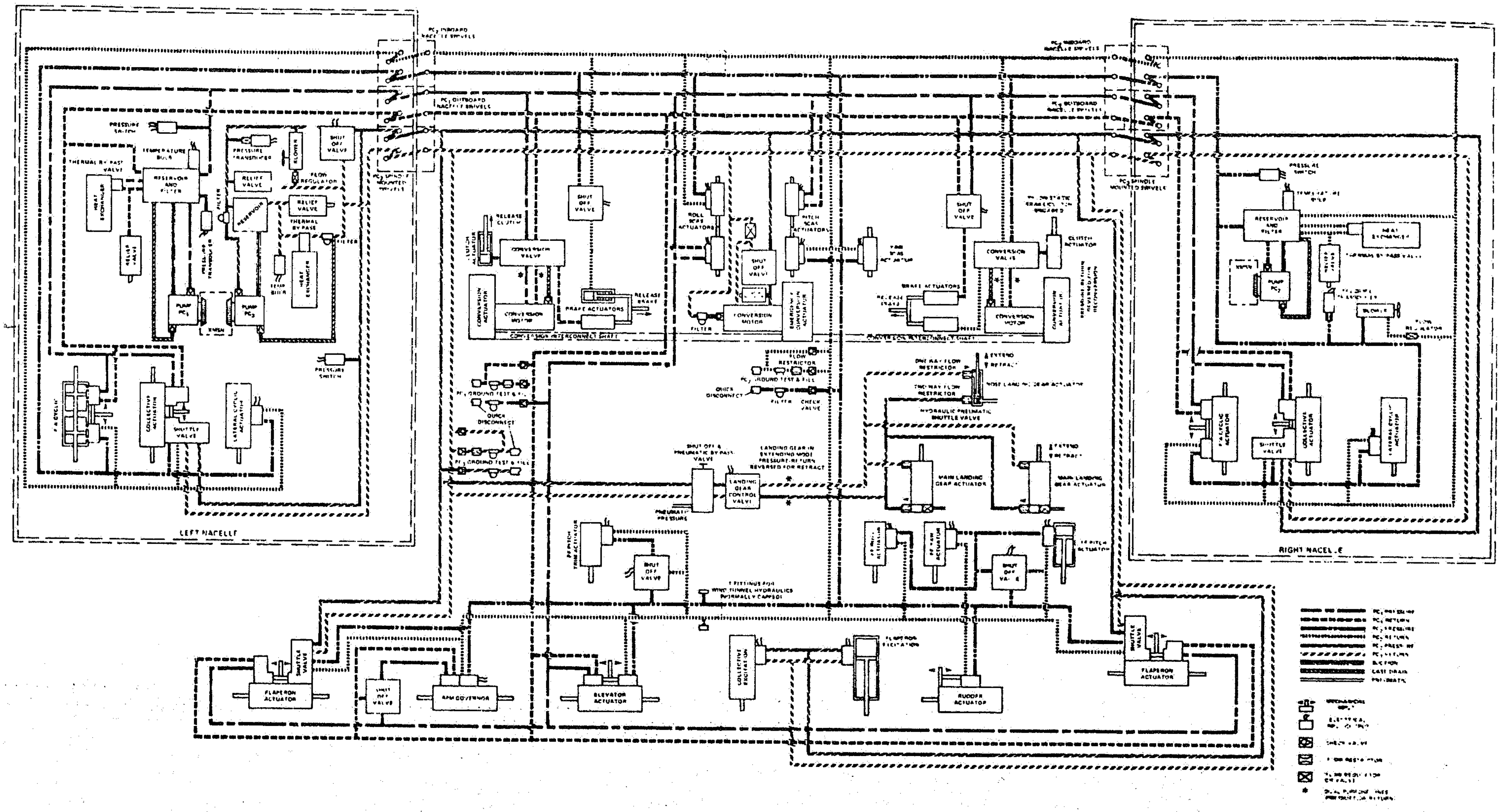
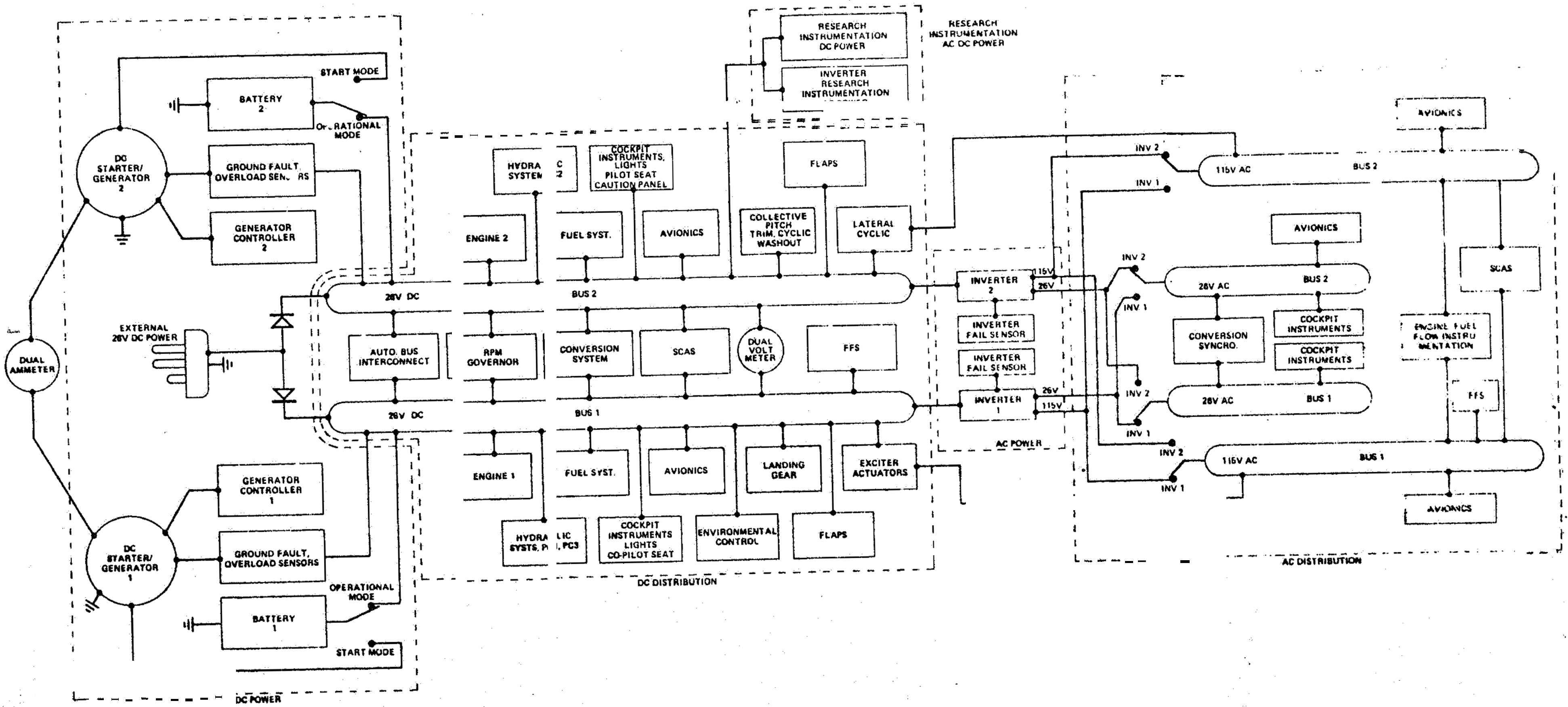


Figure 4-1[illegible] Hydraulic System Schematic



NOTES. 1 AIRFRA ME GROUNDING USE
2. ALL CI CUITS OVERLOAD P

Figure 4-13 - Electrical system block diagram

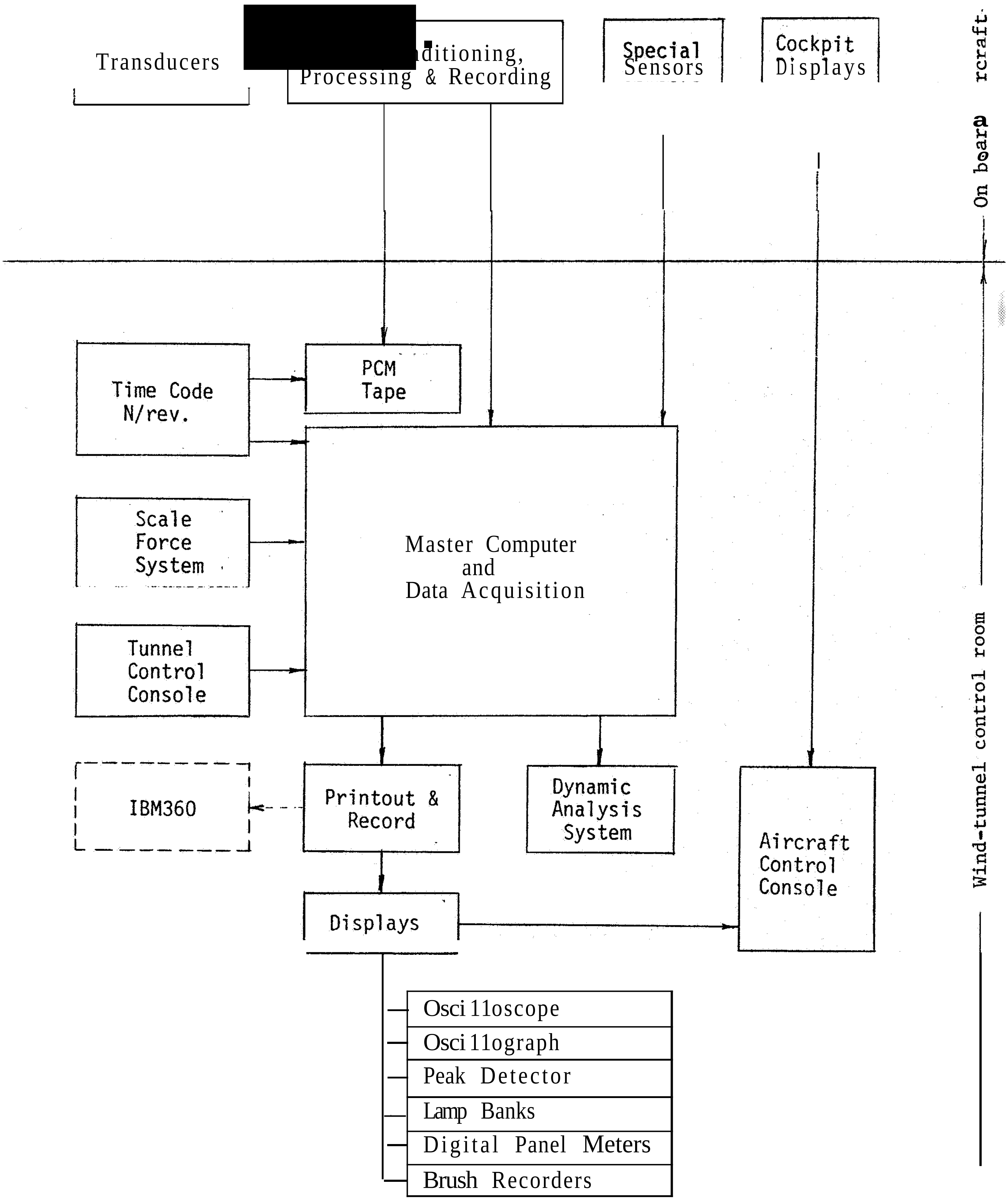


Figure 4-14.- Data system block diagram

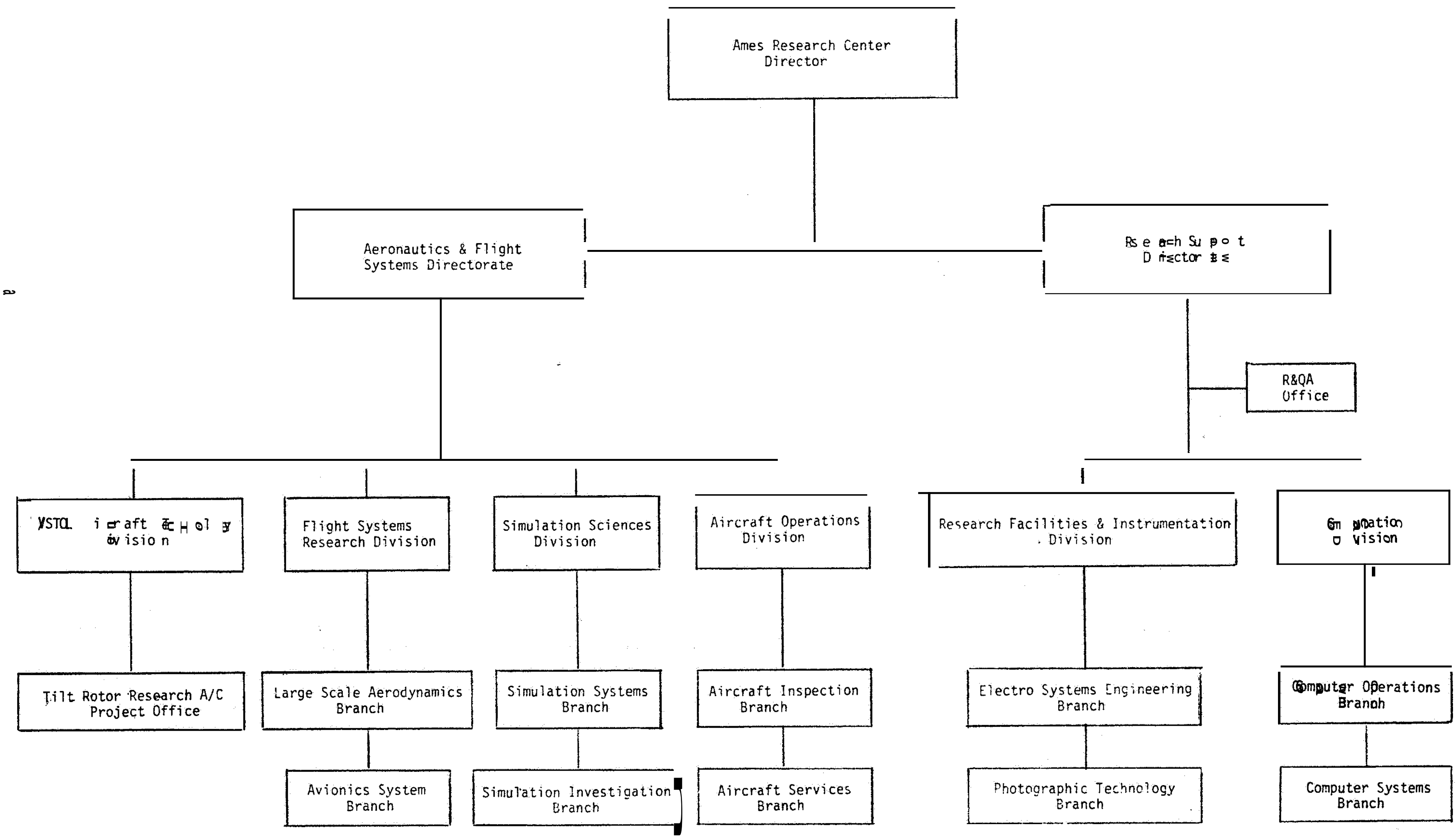


Figure 6-1.- Organizational structure of support elements.

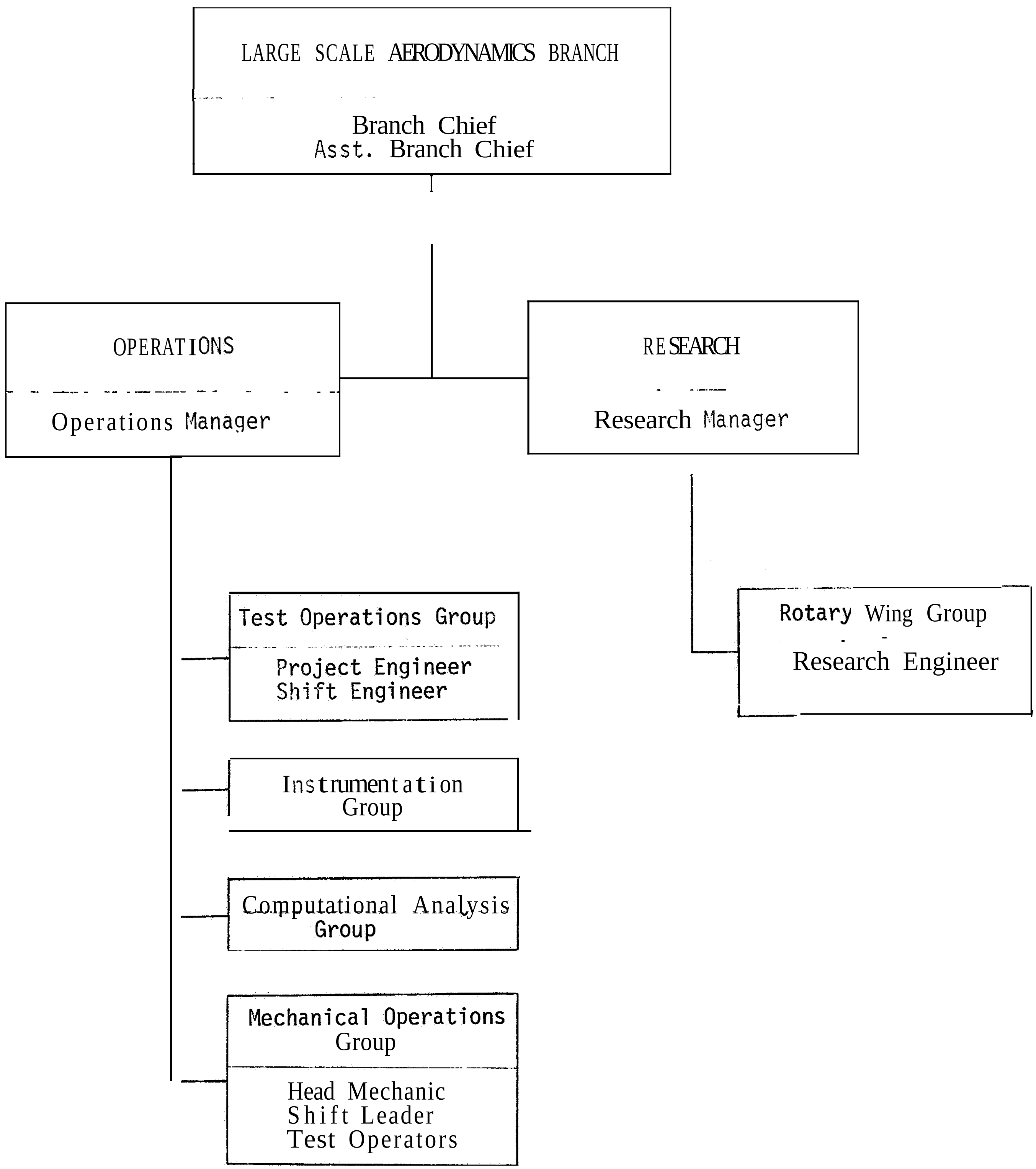


Figure 6-2. - Wind-tunnel staff organization.

1. Report No. NASA TM-78562 AVRADCOM Tech.Rep. 79-7(AM)	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle NASA/ARMY XV-15 TILT ROTOR RESEARCH AIRCRAFT WIND-TUNNEL TEST PROGRAM PLAN		5. Report Date
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7. Author(s) James A. Weiberg and Martin D. Maisel		8. Performing Organization Report No. A-7740
		10. Work Unit No. 744-01-01
9. Performing Organization Name and Address Ames Research Center, NASA, and AVRADCOM Research and Technology Laboratories Moffett Field, Calif. 94035		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D. C. 20546 and U.S. Army Aviation Research and Development Command, St. Louis, MO 93166		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The program plan for conducting wind-tunnel tests of the NASA/Army XV-15 Tilt Rotor Research Aircraft is described. This aircraft is a proof-of-concept vehicle and a research tool for integrated wind tunnel, flight simulation, and flight test investigations. Discussions of special design provisions, safety considerations and management structure for conduct of the wind-tunnel tests are included in this report.

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